

146. A) Gen. Cat.--Alteration studies

- B) Gieskes, J. M.; Kastner, M.; Warner, T. B., 1975, Evidence for extensive diagenesis, Madagascar Basin, Deep Sea Drilling Site 245: *Geochimica et Cosmochimica Acta*, v. 39, no. 10, p. 1385-1393.

- C) Purpose: identify diagenetic reactions that could cause observed concentration gradients.

Methods: SEM, petrography, use of published data.

Results: interstitial dissolved Ca, Mg, and Sr show pronounced concentration gradients. Concentration changes in Ca and Mg are related to basalt alteration; those of Sr are related to calcium carbonate recrystallization processes. High Fe and Mn in sediments can be related to low T alteration of basaltic glasses and not necessarily hydrothermal alteration.

147. A) Gen. Cat.--Alteration studies

B) Heller-Kallai, L., 1975, Montmorillonite - alkali halide interaction:
a possible mechanism for illitization: Clays and Clay Minerals,
v. 23, no. 6, p. 462-467.

C) Purpose: investigate the reaction products of montmorillonite-KBr mixtures.

Methods: XRD, AAS, SEM.

Results: reaction of montmorillonite and KBr at temperatures ranging from 300-520°C, for 1 to 192 hours, yields interstratified montmorillonite-illite as a product. It is speculated that reaction of montmorillonite with other halides or proton acceptors may result in illitization in nature.

148 . A) Gen. Cat.--hydrothermal alteration

B) Kockel, F.; Mollat, H.; Gundlach, H., 1975, Hydrothermally altered and (copper) mineralized porphyritic intrusions in the Serbo-Macedonian Massif (Greece): Mineralium Deposita, v. 10, no. 3, p. 195-204.

C) Purpose: to discuss several hydrothermally altered and mineralized intrusions within the Serbo-Macedonian Massif.

Methods: petrography, chemical analyses (AA)

Results: hydrothermal alterations within the stocks and as haloes in the surrounding country rock are widespread, the phyllic and the propylitic alteration facies being predominant, whereas the potassic facies seems to be lacking.

149 . A) Gen. Cat.--Hydrothermal alteration

B) Kolmer, H., 1975, Geochemical aspects of genesis of kaolinite, alunite, and silica minerals in the vicinity of the trass-deposit near Gleichenberg, Styria: Mineralium Deposita, v. 10, no. 3, p. 249-253.

C) Purpose: to get evidence about post-volcanic alteration and the process of these events by using the behavior of trace elements.

Methods: chemical analyses (XRF, optical emission spectroscopy)

Results: the following idea is proposed about the process of these events; initially kaolinization of latite took place by strongly acid solutions, and trachyte was later altered to alunite by weakly acid solutions. In the last stage trass was formed by solutions that have become alkaline by reacting with the country rock.

150 . A) Gen. Cat.--Alteration studies or Clay minerals in geomedia

B) Merino, E., 1975, Diagenesis in Tertiary sandstones from Kettleman North Dome, California - II. Interstitial solutions: distribution of aqueous species at 100°C and chemical relation to the diagenetic mineralogy: *Geochimica et Cosmochimica Acta*, v. 39, no. 12, p. 1629-1645.

C) Purpose: calculate the concentrations of various species in interstitial solutions at 100°C.

Methods: calculations based on published data.

Results: interstitial brines in these formations are Na - Ca - Cl solutions with subsidiary SO_4 . The brines have pH = 6.3-7.9 at surface temperatures but pH = 8.1-8.7 at 100°C (the assumed in situ temperature). Observations and calculations indicate that quartz, albite, montmorillonite, mica and anhydrite are in equilibrium with the solution. Mg^{2+} and SO_4^{2-} may prevent calcite precipitation, although the solution is supersaturated with calcite. Glauconite and kaolinite are also present but are no longer in equilibrium with the brines.

151. A) Gen. Cat.--Alteration studies or Behavior of clay minerals in geomedial
- B) Sayles, F. L.; Manheim, F. T., 1975, Interstitial solutions and diagenesis in deeply buried marine sediments: results from the Deep Sea Drilling Project: Geochimica et Cosmochimica Acta, v. 39, no. 2, p. 103-127.
- C) Purpose: interpret trends in diagenetic reactions responsible for compositional changes.
- Methods: emission spectrometry, AAS, chemical methods.
- Results: seawater undergoes significant alteration in biogenic deposits; seawater gains Ca^{2+} and Sr^{2+} and loses Mg^{2+} , Na^+ and K^+ . Substitution of Na^+ for Ca^{2+} in secondary phases may be an important mechanism.

152. A) Gen. Cat.--Hydrothermal alteration

- B) Skvortsov, V. A.; Makagon, V. M.; Shmakin, B. M., 1975, The tantalum-bearing pegmatites, exocontact alterations, and primary aureoles in a Siberian deposit: *Geochemistry International*, v. 12, no. 2, p. 233-241.

C) Purpose: describe pegmatites and their aureoles in Siberia.

Methods: petrography, microprobe.

Results: postmagmatic hydrolysis has caused the migration of Na, K, Rb, and Cs into the country rock. Geochemical anomalies are closely related to the mineral aureoles: Li, Rb, and Cs are found in micas, Li in holmquistite, B in tourmaline, and Sn in muscovite. The aureoles are widest in schists and thinnest in amphibolites, but nowhere do they exceed 10 meters in width.

153. A) Gen. Cat.--Hydrothermal alteration
- B) Aleksandrov, S. M., 1976, Geochemical features of metasomatic zoning in the granitization of dolomites: *Geochemistry International*, v. 13, no. 2, p. 125-137.
- C) Purpose: examine the behavior of petrogenic elements during metasomatism.
Methods: calculations based on published data.
Results: data indicate that there are 2 phases in dolomite granitization:
1) production of zoning by transmigmatic solutions; 2) further zoning due to melting in contact skarns. Depth of formation controls whether Mg or Ca skarns are produced. Ca migrates during the second phase.

154. A) Gen. Cat.--Hydrothermal alteration

B) Jacobsen, J. B. E.; McCarthy, T. S., 1976, An unusual hydrothermal copper deposit at Messina, South Africa: *Economic Geology*, v. 71, no. 1, p. 117-130.

C) Purpose: to describe the geology and alteration of the copper deposits of the Messina area.

Methods: petrography, chemical analyses.

Results: extensive aluminum and sodium metasomatism suggest that the fluid which caused mineralization was rich in these components and was capable of albitizing quartz and dissolving silica in the deeper levels of the conduits, thereby producing nepheline normative compositions. The fluids were therefore not of granitic parentage.

155 . A) Gen. Cat.--Alteration, carbonate rocks

B) Moore, D. M., 1976, Carbonate host rock alterations, Zn-Pb District,
Northwestern Illinois: Economic Geology, v. 71, no. 8, p. 1610-1613.

C) Purpose: to study the alteration in carbonate host rocks in the Zn-Pb
district of northwestern Illinois.

Methods: petrography, XRD, chemical analyses.

Results: effects of alteration on the Buckhorn Dolomite and the
Guttenberg Limestone where they are the host rock for Zn and Pb ore
extend at least 100 feet beyond obvious bleaching adjacent to the
ore.

156 . A) Gen. Cat.--Alteration studies

B) Ross, G. J.; Kodama, H., 1976, Experimental alteration of a chlorite into a regularly interstratified chlorite-vermiculite by chemical oxidation: *Clays and Clay Minerals*, v. 24, no. 4, p. 183-190.

C) Purpose: examine the effect of chemical oxidation on an orthochlorite (IIb polytype) of intermediate Fe^{2+} content.

Methods: XRD, AAS, thermogravimetric analysis (TGA) and differential TGA.

Results: orthochlorite was altered to a regularly interstratified chlorite-vermiculite after 4 months reaction in saturated bromine water on a steam bath. Data indicate that oxidation of structural Fe^{2+} is an important mechanism in this transformation. The Fe^{2+} content of a chlorite is thus a control on chlorite alteration.

157 . A) Gen. Cat.--Alteration studies

B) Scott, R.B.; Hajash, A., Jr., 1976, Initial Submarine alteration of basaltic pillow lavas: A microprobe study: American Journal of Science, v. 276, no. 4, p. 480-501.

C) Purpose: Distinguish effects of low and high temperature alteration and crystal fractionation in altered basalts.

Methods: microprobe, AAS, INAA.

Results: at low temperatures, sea water adds K to basalt, either directly to residual glass or through formation of secondary phases. Decreases in Fe and Mn (lost to seawater or secondary phases) is a high temperature process.

158 . A) Gen. Cat.--Hydrothermal alteration of basalt

B) Spooner, E. T. C., 1976, The strontium isotopic composition of seawater, and seawater-oceanic crust interaction: Earth and Planetary Science Letters, v. 31, p. 167-174.

C) Purpose: to quantitatively interpret the observations that 1) the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of seawater strontium ($^{87}\text{Sr}/^{86}\text{Sr} = 0.7069 - 0.7093$ during the Phanerozoic time) is less than the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of dissolved strontium delivered to the oceans by continental run off ($=0.716$) and 2) the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of seawater has not remained the same during Phanerozoic time.

Methods: using figures produced by previous studies to reflect values for seawater $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, continental run-off $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, $^{87}\text{Sr}/^{86}\text{Sr}$ oceanic crust ratios and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of hydrothermally altered seawater discharged from spreading ocean ridges and the rate of that discharge.

Results: it is shown that the observed deviation between continental run-off values of Sr isotope ratios and ocean values of the ratio can be explained by hydrothermally altered seawater Sr isotope ratio values entering and mixing with the ocean water. The change that would take place in the ocean crust (increase in the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio in the upper 4.5 km) is seen in the Troodos Massif, Cyprus. Variations in the strontium ratio over time is explained by variations in land area and therefore amount of continental run-off.

159 . A) Gen. Cat.--Hydrothermal Alteration

B) Wolery, T. J.; Sleep, N. H., 1976, Hydrothermal circulation and geochemical flux at mid-ocean ridges: Journal of Geology, v. 84, no. 3, p. 249-276.

C) Purpose: summarize main aspects of hydrothermal circulation beneath MOR and estimate magnitude of water flow.

Methods: numerical modelling based on published data.

Results: flow rate of seawater through sub-sea-floor hydrothermal systems is estimated at $1.3-9 \times 10^{17}$ g/year. Chemical trends are similar to those found in laboratory experiments (loss of Ca and K, gain of Mg, Na, and H₂O).

Alteration of oceanic crust appears strongly dependent on the presence of permeable features, such as cracks, and may be restricted to major fault zones.

160 . A) Gen. Cat.--Hydrothermal alteration

B) Bachinski, D. J., 1977, Alteration associated with metamorphosed ophiolitic cupriferous iron sulfide deposits: Whalesback Mine, Notre Dame Bay, Newfoundland: Mineralium Deposita, v. 12, no. 1, p. 48-63.

C) Purpose: to examine the alteration associated with the Whalesback stock-work-type ore body.

Methods: petrography, chemical analyses (XRF, other analyses unspecified)

Results: the most striking bulk chemical change in the ore zone is the almost complete leaching of sodium and calcium from the host metabasites. Increases in iron and sulfur contents and erratic enrichment in potassium are also characteristic. No significant changes are shown by SiO_2 , Al_2O_3 , TiO_2 , MgO , and MnO . The alteration occurred before Acadian deformation and chlorite-zone greenschist facies metamorphism.

161. A) Gen. Cat.--Alteration studies

B) Boles, J.R.; Coombs, D.S., 1977, Zeolite facies alteration of sandstones in the Southland Syncline, New Zealand: American Journal of Science, v. 277, no. 8, p.982-1012.

C) Purpose: investigate controls on development of zeolites in Southland Syncline.

Methods: petrography, microprobe.

Results: laumontite, heulandite, and albite occur throughout the section; prehnite exists in the bottom part, and analcime near the top. Laumontite formed at T's as low as 50^o-100^oC; prehnite at T's from 90^o-130^oC. Laumontite, heulandite, prehnite, pumpellyite and calcite are associated mainly with rocks of andesitic parentage. Formation of zeolites is a function of permeability, ionic activity ratios, temperature, P_{CO2}, relationship of P_{Fluid} to P_{Total}, completeness of reactions and parent material.

162 . A) Gen. Cat.--Hydrothermal alteration

B) Chapman, H. J.; Spooner, E. T. C., 1977, ^{87}Sr enrichment of ophiolitic sulfide deposits in Cyprus confirms ore formation by circulating seawater: Earth and Planetary Science Letters, 35, p. 71-78.

C) Purpose: to test if the cupriferous pyrite ore deposits which occur within the pillow lavas/dyke complex sequence of the Troodos Massif were formed in the discharge zones of a geothermal system (hydrothermal)
Methods: analysis of the strontium isotope composition of 13 mineralized samples from four mines in the Massif.

Results: $^{87}\text{Sr}/^{86}\text{Sr}$ ratios are found to be similar to that of Upper Cretaceous seawater, so that the mineralized metabasalt samples have been contaminated with ^{87}Sr relative to initial magmatic strontium isotope ratios of the Troodos ophiolitic complex. Seawater is thus thought to be the sole agent in the mineralization (through hydrothermal means).

163 . A) Gen. Cat.--Hydrothermal alteration

B) Chivas, A. R.; Wilkins, R. W. T., 1977, Fluid inclusion studies in relation to hydrothermal alteration and mineralization at the Koloula Porphyry Copper Prospect, Guadacanal: *Economic Geology*, v. 72, no. 2, p. 153-169.

C) Purpose: to use fluid inclusions to help understand the geology and alteration of the Koloula prospect.

Methods: geologic mapping, petrography, fluid inclusions.

Results: the intermediate and felsic rocks of the younger part of the Koloula igneous complex are host to porphyry copper mineralization, which is characterized by two well-defined separate alteration systems. Homogenization temperatures obtained from moderately and highly saline inclusions range up to approximately 700°C in the A alteration system and up to 480°C in the B alteration system.

164 . A) Gen. Cat.--Hydrothermal alteration

B) DeWit, M. J.; Dutch, S.; Kligfield, R.; Allen, R.; Stern, C., 1977,
Deformation, serpentinization, and emplacement of a dunite complex,
Gibbs Island, South Shetland Island: possible fracture zone tectonics:
Journal of Geology, v. 85, no. 6, p. 745-762.

C) Purpose: describe the geology of Gibbs Island.

Methods: field mapping, petrography .

Results: dunite has undergone 2 periods of deformation. The first was pre-
emplacement and resulted in the formation of antigorite. The second period
resulted in the formation of a basal chrysotile zone, along which the complex
was emplaced. Data indicate that the dunite represents a mantle intrusion
into a fault or fracture zone.

165 . A) Gen. Cat.--Alteration studies

B) Eberl, D.; Hower, J., 1977, The hydrothermal transformation of sodium and potassium smectite into mixed layer clay: *Clays and Clay Minerals*, v. 25, no. 3, p. 215-227.

C) Purpose: examine chemical interactions in clays at high temperatures.

Methods: XRD, wet chemical techniques.

Results: reactions were strongly influenced by interlayer chemistry.

K-smectite converted to randomly interstratified illite/smectite (I/S)

and then to ordered interstratified I/S. Na-smectite converted to an

aluminous beidellite, then to rectorite and finally to paragonite.

Ordering formed in Na clays at high expandabilities, whereas it never

appeared in K clays above 35% expandable.

166 . A) Gen. Cat.--Alteration

B) Fletcher, C. J. N., 1977, The Geology, mineralization, and alteration of Ilkwang Mine, Republic of Korea. A Cu-W-bearing tourmaline breccia pipe: Economic Geology, v. 72, no. 5, p. 753-768.

C) Purpose: to describe the geology, mineralization, and alteration of the Ilkwang Mine.

Methods: geologic mapping, chemical analyses, K-Ar dating.

Results: alteration zones have developed both within the brecciated fragments and around the pipe within the quartz monzonite. The majority of the stock lies within the propylitic zone, which has been divided into two subzones: an outer tourmaline subzone characterized by the development of tourmaline rosettes, and an inner garnet subzone which lies within 10 m of the pipe margins.

167 . A) Gen. Cat.--Hydrothermal alteration, basalts

B) Fujishima, K. Y.; Fan, P., Hydrothermal mineralogy of Keolu Hills, Oahu, Hawaii: American Mineralogist, v. 62, no. 5 and 6, p. 574-582 , 1977.

C) Purpose: to analyze the mineralogical composition of the hydrothermally altered Keolu Hills basalts by X-ray diffraction, to determine if clay-mineral alteration produced zoning in those rocks, and to correlate the mineralogy with previous studies of hydrothermal alteration.

Methods: XRD, petrography.

Results: the three clay types found in the altered rock form two types of zones: (1) a vertical zonal boundary between chlorite (lower) and mixed-layer chlorite-vermiculite (higher) at elevations greater than 150 feet; and (2) a horizontal zonation between mixed-layer chlorite-montmorillonite and chlorite (or mixed-layer chlorite-vermiculite) aureole. The zonations were caused by changes that took place in the chemistry of the hydrothermal solutions as the solutions progressed through the flows.

168. A) Gen. Cat.--Hydrothermal alteration of basalt

B) Seyfried, W.; Bischoff, J. L., 1977, Hydrothermal transport of heavy metals by seawater: The role of seawater/basalt ratio: Earth and Planetary Science Letters, v. 34, p. 71-77.

C) Purpose: to study the effects of hydrothermal seawater on basalt to test if reported metal deposits are the result of such processes.

Methods: 4 gm of fresh basalt glass (crushed) were reacted with 200 gm of artificial SO_4 -free seawater at 260°C and 500 bars.

Results: the basalt was efficiently leached and the seawater maintained heavy metals in solution. Cu, Zn, and Ba are transferred in significant proportions to the aqueous phase, while Fe and Mn attain concentrations of 45 and 20 ppm, respectively, as the basalt is completely made over to magnesian smectite. High metal solubility is a function of acidity maintained by large excess of dissolved Mg and equilibria with the alteration phase. Metal concentrations and relative proportions are consistent with limits for fluids which produced East Pacific Rise metaliferous sediments.

- 169 . A) Gen. Cat.--Hydrothermal alteration .
- B) Sigurdsson, H., 1977, Chemistry of the Crater Lake during the 1971-1972 Soufriere eruption: Journal of Volcanology and Geothermal Research, v. 2, p. 165-186.
- C) Purpose: to understand changes in the waters of the Crater Lake brought on by eruption of lava into the lake.
- Methods: analysis of waters after eruption of lavas into the lake and comparison of this with earlier lake analysis.
- Results: 50,000 tons of dissolved solids were taken into solution and 9000 tons of ferric oxide precipitated in syngenetic sediments on the lake bottom. Detailed chemistry is discussed.

170. A) Gen. Cat.--Alteration studies

B) Spooner, E. T. C.; Beckinsale, R. D.; England, P. C.; Senior, A., 1977, Hydration, ^{18}O enrichment and oxidation during ocean floor hydrothermal metamorphism of ophiolitic metabasic rocks from E. Liguria, Italy: *Geochimica et Cosmochimica Acta*, v. 41, no. 7, p. 857-871.

C) Purpose: describe chemical behavior of hydration, $\delta^{18}\text{O}$, and degree of oxidation.

Methods: mass spectrometry, XRF, chemical methods.

Results: hydrothermal metamorphism of this basalt resulted in hydration, oxidation, and ^{18}O enrichment. $\delta^{18}\text{O}$ and oxidation ratio ($\text{Fe}_2\text{O}_3/\text{FeO}$) both increase in the original direction of increasing depth. Data indicate unidirectional downward flow; mass transfer was accomplished by infiltration metasomatism or diffusion. Water/rock ratio is estimated at 2000:1.

171. A) Gen. Cat.--Alteration studies

B) Spooner, E. T. C.; Chapman, H. J.; Smewing, J. D., 1977, Strontium isotopic contamination and oxidation during ocean floor hydrothermal metamorphism of the ophiolitic rocks of the Troodos Massif, Cyprus: *Geochimica et Cosmochimica Acta*, v. 41, no. 7, p. 873-890.

C) Purpose: use strontium isotopes to ascertain the alteration history of ophiolite.

Methods: XRF, mass spectrometry.

Results: altered rocks have been contaminated by heavier strontium, indicating that seawater was the hydrothermal agent. Seawater penetrated about 2 km into the oceanic crust. Sr contamination indicates that the water/rock ratio was at least 15:1; the oxidation profile yields estimates of water/rock = 3000:1.

172. A) Gen. Cat.--Alteration studies

B) Tomita, K., 1977, Experimental transformation of 2M sericite into a rectorite-type mixed-layer mineral by treatment with various salts: Clays and Clay Minerals, v. 25, no. 4, p. 302-308.

C) Purpose: ascertain the mechanism of formation of an interstratified clay mineral from 2M sericites.

Methods: XRD.

Results: a rectorite-type mixed layer was formed when 2M sericite was boiled in solutions of NaNO_3 , Na_2SO_4 , CaSO_4 , CaCl_2 , MgCl_2 and MgSO_4 . A random mica/montmorillonite mixed layer was formed from 1M sericite. The transformation can be explained by a change in the hydroxyl bond direction after leaching of the interlayer K^+ ion.

173 . A) Gen. Cat.--Alteration studies

B) Busenberg, E., 1978, The products of the interaction of feldspars with aqueous solutions at 25°C: *Geochimica et Cosmochimica Acta*, v. 42, no. 11, p. 1679-1686.

C) Purpose: determine processes that control aqueous chemistry during artificial feldspar weathering.

Methods: XRD, SEM, electron diffraction, differential thermal analysis, chemical analyses.

Results: Al activity was controlled by pH and solubility of microcrystalline gibbsite; after 100 hours of dissolution pH and microcrystalline halloysite control Al and H_4SiO_4 activities. Halloysite was the only phase formed in distilled water. Solutions containing high concentrations of Ca, Mg, K, and SiO_2 yielded halloysite, montmorillonite, and other clays.

log solubility products of gibbsite = -32.78 ± 0.04

log K for hydrolysis of halloysite = 11.58 ± 0.05

174 . A) Gen. Cat.--Hydrothermal alteration

B) Hall, W. E.; Rye, R. O.; Doe, B. R., 1978, Wood River mining district, Idaho - intrusion-related lead-silver deposits derived from country rock source: Journal of Research of the USGS, v. 6, no. 5, p. 579-592.

C) Purpose: to describe and determine origin of lead-silver deposits in Wood River mining district.

Methods: stable isotope and fluid inclusion analysis.

Results: mineralogy of the deposits is given with $\delta^{34}\text{S}$ and $\delta^{18}\text{O}$ of those minerals and data on their fluid inclusions. With this data, along with the fact that plutons are nearby, the authors discuss the hydrothermal regime that formed the deposits.

175. A) Gen. Cat.--Hydrothermal alteration

B) Hawksworth, C. J.; Elderfield, H., 1978, The strontium isotopic composition of interstitial waters from sites 245 to 336 of the Deep Sea Drilling Project: Earth and Planetary Science Letters, v. 40, p. 423-432.

C) Purpose: to interpret the strontium isotope composition of the interstitial water from some samples of the Deep Sea Drilling Project (DSDP).

Methods: water was extracted from each sample by ion exchange techniques. $^{87}\text{Sr}/^{86}\text{Sr}$ was measured by mass spectrometer with online computer facilities.

Results: analysis of waters from leg 25, site 245 and leg 38 site 336 of the DSDP show that enrichment with depth of Sr^{2+} is caused both by the alteration of volcanic material and by the introduction of strontium derived from calcium carbonate. $^{87}\text{Sr}/^{86}\text{Sr}$ ratios range from 0.70913 to 0.70794 at site 245 and 0.70916 to 0.70694 at site 336. This low ratio compared to seawater reflects release of Sr from a volcanic source having an $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of about 0.7034 at site 336. At this site the source seems to be volcanic ash and not basaltic basement which acts as sink for Sr^{2+} during low temperature weathering.

176. A) Gen. Cat.--Alteration studies

B) Humphris, S. E.; Thompson, G., 1978, Hydrothermal alteration of oceanic basalts by seawater: *Geochimica et Cosmochimica Acta*, v. 42, no. 1, p. 107-125.

C) Purpose: describe changes (chemical and mineralogical) that occur during the formation of greenschist facies metabasalts.

Methods: petrography, bulk mineralogy analysis.

Results: typical alteration assemblage is albite-actinolite-chlorite-epidote with minor quartz and pyrite. Chlorite-rich assemblages are highly altered; epidote-rich assemblages show less alteration in chemistry. SiO_2 and CaO are leached from the basalt, while MgO and H_2O are taken up; no trends were observed for K_2O or Na_2O . Thus basalt alteration provides a sink for Mg, accounting for its depletion in sea water. Redox changes during alteration have no effect on the present day oxidation state of the hydrosphere or atmosphere.

177 . A) Gen. Cat.--Alteration studies

B) Humphris, S. E.; Thompson, G., 1978, Trace element mobility during hydrothermal alteration of oceanic basalts: *Geochimica et Cosmochimica Acta*, v. 42, no. 1, p. 127-136.

C) Purpose: present trace element analyses of a suite of hydrothermally altered basalts.

Methods: spectrometry, spectrophotometry using d.c. argon plasma.

Results: Sr, like Ca, is leached from basalt, as is Cu, which can be precipitated in veins as sulphides. Fe, B, Li, Ba, Mn, Ni and Co all exhibit some mobility. V, Y, Zr, and Cr do not appear affected by alteration. Like Cu, Ni, Co and Zn can be precipitated in sulfide phases. Overall, the process of hydrothermal alteration produces a metal-enriched solution.

B) Keith, T. E. C.; Muffler, L. J. P., 1978, Minerals produced during cooling and hydrothermal alteration of ash flow tuff from Yellowstone Drill Hole Y-5: Journal of Volcanology and Geothermal Research, v. 3, p. 373-402.

C) Purpose: to describe and analyze primary and secondary mineralization in Tuff from Yellowstone.

Methods: cores from the Tuff were analyzed chemically (x-ray diffraction, etc.)

Results: mineralogy in the tuff is described and discussed in detail.

179. A) Gen. Cat.--Hydrothermal alteration

B) Kotov, N. V.; Shinkarev, N. F.; Donskikh, A. V.; Domnina, M. I., 1978,
High-temperature Na-carbonate metasomatism in a haplobasalt
system: *Geochemistry International*, v. 15, no. 1, p. 126-134.

C) Purpose: examine the origin of large bodies of nephelinites, leucitites,
and kalsilites.

Methods: XRD, petrography.

Results: in Na_2CO_3 solution, feldspars are replaced by nepheline and
cancrinite at low concentrations and by cancrinite alone at higher
(above 0.5M) concentrations. Diopside is produced in 0.5M solutions,
but is replaced by amphibole at higher concentrations. Transition of
haplobasalt to soda carbonatites occurs in the presence of 5M NaCO_3 .
Al acts as an analog of Si when alkalinity is high, entering tetrahedral
positions in leucocratic minerals.

180 . A) Gen. Cat.--Hydrothermal alteration

B) Leonard, R. B.; Janzer, V. J., 1978, Natural radioactivity in geothermal waters, Alhambra hot springs and nearby areas, Jefferson County, Montana: Journal of Research of the USGS, v. 6, no. 4, p. 529-540.

C) Purpose: determine amount, characteristics and origin of radioactivity in Alhambra hot springs.

Methods: chemical determination of origin of radioactivity.

Results: the type of waters that the high radioactivity was found in is described (sodium bicarbonate). Water composition changes with depth are given. Origin of the high radioactivity in these waters is discussed.

181. A) Gen. Cat.--Alteration studies

B) Mottl, M. J.; Holland, H. D., 1978, Chemical exchange during hydrothermal alteration of basalt by seawater - I. Experimental results for major and minor components of seawater: *Geochimica et Cosmochimica Acta*, v. 42, no. 8, p. 1103-1115.

C) Purpose: describe silica alteration mineralogy and describe controls on elemental composition of solutions.

Methods: gas chromatography, AAS, DC-arc emission spectrography, spectrophotometry.

Results: most elements approached equilibrium in the time of the experiment (2 - 20 months). Resulting solutions closely resemble geothermal fluids at Reykjanes, Iceland. Mg, Na, Sr, and SO_4^- were removed from seawater; SiO_2 , Ca, K, Ba, B, and CO_2 were added to seawater. SiO_2 concentrations were controlled by quartz saturation. Na and Mg were balanced in the exchange by Ca.

182 . A) Gen. Cat.--Alteration studies

B) Nesbitt, H. W.; Bricker, O. P., 1978, Low temperature alteration processes affecting ultramafic bodies: *Geochimica et Cosmochimica Acta*, v. 42, no. 4, p. 403-409.

C) Purpose: discuss the chemical processes that effect the alteration of ultramafics.

Methods: use of published and unpublished data.

Results: olivine and opx convert to brucite, serpentine, and talc under low-T's in the presence of water; alteration is therefore a non-equilibrium process. Dissolution of primary phases is rapid relative to precipitation of secondary phases (thus precipitation is the rate controlling step in the formation of a secondary assemblage, while dissolution controls water chemistry). Alteration continues until at least one primary phase is in equilibrium with brucite, chrysotile, or talc.

183. A) Gen. Cat.--Alteration studies

B) Rozenson, I.; Heller-Kallai, L., 1978, Reduction and oxidation of Fe^{3+} in dioctahedral smectites - III. Oxidation of octahedral iron in montmorillonite: Clays and Clay Minerals, v. 26, no. 2, p. 88-92.

C) Purpose: study the factors affecting oxidation of structural iron in montmorillonite.

Methods: XRD, AAS.

Results: structural Fe^{2+} is readily oxidized by contact with water or salt solutions, or by mild heating. Rate of oxidation depends on the exchangeable cations. Chemical treatment of montmorillonite, such as contact with Cu^{2+} or H_2O_2 solutions, is highly conducive to oxidation, as is high interlayer acidity.

184 . A) Gen. Cat.--Hydrothermal alteration

B) Stettler, A.; Allègre, C. J., 1978, ^{87}Rb - ^{87}Sr studies of waters in a geothermal area: the Cantal, France: Earth and Planetary Science Letters, v. 38, p. 364-372.

C) Purpose: to study the waters in a geothermal area.

Methods: determining K, Rb and Sr concentrations and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in fresh surface waters, a rain water sample and five geothermal waters from the Cantal volcanic area in the Massif Central, France.

Results: a comparison with appropriate rock types of the region showed no apparent chemical and isotope fractionation occurring in the fresh water-surface rock system. The thermo-mineral water results suggest that all springs discharge dissolved Sr from the following contributors: Hercynian granito-metamorphic basement, lacustrine sediments underlying the volcano, Miocene-Pliocene volcanic rocks of basaltic to rhyolitic composition.

185 .A) Gen. Cat.--Alteration studies

B) Tomita, K., 1978, Experimental transformation of 2M sericite into a rectorite-type mixed-layer mineral by treatment with various salts.

II. Experiments using a magnetic stirrer and a centrifuge: Clays and Clay Minerals, v. 26, no. 3, p. 209-216.

C) Purpose: discern the mechanism of formation of a rectorite-type mineral from 2M sericite.

Methods: XRD, IR spectra.

Results: treatment with Na salts transforms 2M sericite into an interstratified mineral of the rectorite type, and 1M sericite into a random mixed layer mineral. Formation of the rectorite product is due to changes in (OH) bond direction after leaching of K^+ from sericite.

186 . A) Gen. Cat.--Hydrothermal alteration

B) Ambler, E. P., 1979, Alteration and mineralization associated with a vesicular dike near Yeoval in New South Wales, Australia: *Economic Geology*, v. 74, no. 1, p. 67-76.

C) Purpose: to describe a zonally altered and mineralized vesicular dike, 15 m in width, which is associated with the felsic to intermediate intrusive rocks of the Yeoval Diorite Complex.

Methods: petrography, chemical analyses.

Results: it is proposed that vesiculation of the dike occurred after it intruded the granodiorite and after an abrupt fall in the confining pressure which may be related to pressure release in the parent stock. The zone of vesicle development was more permeable than the massive outer rind of the dike and allowed passage of solutions migrating upward from the parent stock. These solutions caused changes in mineralogy and produced chemical zonation.

187 . A) Gen. Cat.--Hydrothermal alteration

B) Bailey, D. G.; Hodgson, C. J., 1979, Transported altered wall rock in
laharic breccias at the Cariboo-Bell Cu-Au porphyry deposit,
British Columbia: Economic Geology, v. 74, no. 1, p. 125-128.

C) Purpose: to report radiometric dates and geological relationships
between intrusive complexes and intruded rocks at the Cariboo-Bell
Cu-Au porphyry deposit.

Methods: geologic mapping, petrography, radiometric dating.

Results: it is concluded that felsic volcanism, plutonism, and ore
deposition in the Cariboo-Bell area were essentially synchronous and
that an important indicator of these events is epidote-rich altered
clasts in laharic breccias.

188 . A) Gen. Cat.--Alteration studies

B) Boles, J.R.; Surdam, R.C., 1979, Diagenesis of volcanogenic sediments in a Tertiary saline lake; Wagon Bed Formation, Wyoming: American Journal of Science, v. 279, no. 7, p. 832-853.

C) Purpose: document diagenesis in a fresh to saline lake deposit.

Methods: petrography, microprobe, AAS.

Results: 3 diagenetic facies have been determined in these tuffaceous terrestrial/lacustrine sediments: 1) fresh-glass smectite facies, 2) clinoptilolite-heulandite facies, 3) k-spar carbonate facies. Authigenic clays formed after burial. Distribution of facies is controlled by pore-water composition. Clinoptilolite-forming fluids have log Na+K/Ca+Mg mole ratios of about -0.3. Coexistence of k-spar and sepiolite indicates log K+/H+ was at least 3.0 in pore water.

189. A) Gen. Cat.--Hydrothermal alteration

B) Brimhall, G. H., Jr., 1979, Lithologic determination of mass transfer mechanisms of multiple-stage porphyry copper mineralization at Butte, Montana: Vein formation by hypogene leaching and enrichment of potassium-silicate protore: Economic Geology, v. 74, no. 3, p. 556-589.

C) Purpose: to develop a new and general lithologic approach for the analysis of the interdependence of wall-rock alteration and ore deposition during successive mineralization events.

Methods: thermodynamic analysis, geologic mapping, petrography, drill core analysis, chemical analyses.

Results: it is proposed that the Main Stage vein-forming events represent deep hydrothermal hypogene leaching and enrichment phenomena, analogous in certain respects to the formation of supergene enrichment blankets.

190. A) Gen. Cat.--Alteration studies

B) Eslinger, E.; Highsmith, P.; Albers, D.; deMayo, B., 1979, Role of iron reduction in the conversion of smectite to illite in bentonites in the disturbed belt, Montana: *Clays and Clay Minerals*, v. 27, no. 5, p. 327-338.

C) Purpose: determine whether a correlation exists between $\text{Fe}^{2+}/\text{Fe}^{3+}$ and the percentage of illite layers.

Methods: XRD, Mossbauer spectroscopy.

Results: a positive correlation ($r=0.89$) exists between the percentage of structural iron that is Fe^{2+} and the amount of fixed interlayer K in illite/smectite interlayers (I/S). The increase in $\text{Fe}^{2+}/\text{Fe}^{3+}$ with increasing percentage of illite in I/S is attributed to the oxidation of organic matter. Reduction of Fe^{3+} to Fe^{2+} may contribute as much as 30% to the total structural charge increase; the remaining increase is due to substitution of Al^{3+} for Si^{4+} in tetrahedral sites.

191 . A) Gen. Cat.--Hydrothermal alteration

B) Ferry, J. M., 1979, Reaction mechanisms, physical conditions, and mass transfer during hydrothermal alteration of mica and feldspar in granitic rocks from south-central Maine, U.S.A.: Contributions to Mineralogy and Petrology, v. 68, no. 2, p. 125-139.

C) Purpose: to present results of a petrologic investigation of the origin of altered feldspar and mica in plutonic igneous rocks.

Methods: petrography, electron microprobe.

Results: modal analysis of the altered granitic rock, combined with estimates of the chemical reactions associated with the alteration, indicates that small but significant amounts of CO_2 , H_2O , K, H, Mg, Fe, Mn, Na, and Ti were added to the granites during mica and feldspar alteration. Similar reasoning dictates that Ca was subtracted from these granites during the alteration.

- 192 . A) Gen. Cat.--Hydrothermal alteration
- B) Fournier, R. O., 1979, Geochemical and hydrologic considerations and the use of enthalpy-chloride diagrams in the prediction of underground conditions of hot spring systems: Journal of Volcanology and Geothermal Research, v. 5, p. 1-16.
- C) Purpose: to shed light on hydrothermal processes underground.
- Methods: plotting enthalpy against chloride content of waters.
- Results: enthalpy vs. chloride is thought to be a useful tool to estimate underground conditions and is shown in examples from Cerro Prieto, Mexico, Orakeikorako, New Zealand and Yellowstone.

- 193 . A) Gen. Cat.--Hydrothermal alteration
- B) Fournier, R. O.; Sorely, M. L.; Mariner, R. H.; Truesdell, A. H., 1979,
Chemical and isotopic predictions of aquifer temperatures in the
geothermal system at Long Valley, California: Journal of
Volcanology and Geothermal Research, v. 5, p. 17-34.
- C) Purpose: to use data to infer aquifer temperatures.
Methods: enthalpy-chloride plots and oxygen and deuterium isotope data.
Results: temperatures were estimated from the enthalpy-chloride plots
and were consistent with isotope data.

194 . A) Gen. Cat.--Geothermal systems

B) Klusman, R. W.; Landress, R. A., 1979, Mercury in soils of the Long Valley, California, Geothermal system: Journal of Volcanology and Geothermal Research, v. 5, p. 49-65.

C) Purpose: to use anomalously high Hg concentrations in soils to explore for geothermal systems and the importance of secondary controls on Hg concentrations in soil above geothermal systems.

Methods: samples were collected from various areas above the geothermal system and analyzed for Hg content.

Results: two populations of Hg were found, one affected by the geothermal system and one not. Secondary controls are discussed.

195. A) Gen. Cat.--Alteration studies

- B) Lawrence, J. R., Drever, J. I.; Anderson, T. F.; Brueckner, H. K., 1979,
Importance of alteration of volcanic material in the sediments of
Deep Sea Drilling Site 323: chemistry, $^{18}\text{O}/^{16}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$:
Geochimica et Cosmochimica Acta, v. 43, no. 4, p. 573-588.

C) Purpose: evaluate magnitudes of various alteration reactions.

Methods: mass spectrometry, XRD, AAS, SEM.

Results: downhole decreases in ^{18}O , Mg^{2+} , K^{+} , increase in Ca^{2+} and low $^{87}\text{Sr}/^{86}\text{Sr}$ (.7067) are caused by alteration of volcanic ash, and to a lesser degree, basalt. Data suggests that alteration was accomplished during the last 13 million years. Secondary minerals are smectite, K-spar, clinoptilolite, and calcite.

196. A) Gen. Cat.--Alteration studies

B) Mottl, M. J.; Holland, H. D.; Corr, R. F., 1979, Chemical exchange during hydrothermal alteration of basalt by seawater - II. Experimental results for Fe, Mn, and sulphur species: *Geochimica et Cosmochimica Acta*, v. 43, no. 6, p. 869-884.

C) Purpose: identify controls on chemical concentrations in solutions in a natural setting.

Methods: flameless AAS, DC-arc emission spectrography, chemical methods, XRD.

Results: concentrations of Fe, Mn, and S reached steady state at 400 - 500°C, but not at 200 - 300°C. Concentrations of Fe and Mn increased greatly with temperature. Cu was strongly leached from basalt. Sulfate reduction to sulfide, with water/rock = 1, was 5 - 10% at 300°C and > 95% at 500°C. S content generally exceeded Fe content on a molal basis. Rate of S reduction was a function of: 1) temperature, 2) crystallinity and original S in sample, 3) water/rock ratio.

197 . A) Gen. Cat.--Alteration

B) Newberry, R. J. J., 1979, Polytypism in molybdenite (II); relationships between polytypism, ore deposition/alteration stages and rhenium contents: *American Mineralogist*, v. 64, no. 7 and 8, p. 768-775.

C) Purpose : to analyze data on several porphyry copper and skarn samples to suggest relations between mineralization stages, rhenium contents, and polytype abundances in porphyry copper, porphyry molybdenum, and copper skarn deposits.

Methods: petrography, electron microprobe, XRD.

Results: relationships between 3R molybdenite abundance and rhenium contents can be explained by the effects of initial rhenium contents, recrystallization, and rhenium leaching.

198. A) Gen. Cat.--Hydrothermal alteration

B) Noble, D. C.; Scherkenbach, D. A.; Drexler, J. W.; Mendoza, J.;
Dyzaguirre, V. R., 1979, Age of porphyry intrusion, potassic
alteration, and related skarn mineralization, Antamina District,
Northern Peru: Economic Geology, v. 74, no. 4, p. 928-930.

C) Purpose: to report K-Ar ages on hydrothermally altered rocks from
three petrographically distinct phases of the composite porphyry
stock of Antamina.

Methods: K-Ar dating, chemical analyses, petrography, fluid inclusions.

Results: intrusion, alteration, and related skarn mineralization in
the district took place over a short period of time about 10 million
years ago.

199. A) Gen. Cat.--Hydrothermal alteration

B) Purtov, V. K.; Ogorodova, V. Y.; Anfilogov, V. N., 1979, Reactions of water with volcanogenic rocks at high T and P: *Geochemistry International*, v. 16, no. 5, p. 142-147.

C) Purpose: examine influence of volcanic rocks on compositions of hydrothermal solutions.

Methods: flame photometry, colorimetry.

Results: rock/water reaction results in release of silica to water almost to the point of quartz saturation. Solutions in equilibrium with vitreous phases are supersaturated with respect to crystalline phases; this is especially pronounced for alkalis and alkali containing phases. Vitreous groundmass decomposes more quickly in a neutral medium than in a low pH medium.

200 . A) Gen. Cat.--Alteration studies

B) Seyfried, W. E., Jr.; Bischoff, J. L.; 1979, Low temperature basalt alteration by seawater: an experimental study at 70°C and 150°C: *Geochimica et Cosmochimica Acta*, v. 43, no. 12, p.1937-1947.

C) Purpose: examine temperature dependence of exchange reactions and mechanisms of secondary mineral formations.

Methods: chemical analyses, AAS, microprobe, XRD.

Results: both a glass and a diabase were studied. At 70°C, the experiment produced a slight but continuous loss of Mg, Na, K and enrichment of Ca and SiO₂ in seawater while pH decreased slowly. At 150°C, Mg and SO₄ were rapidly lost while Ca, SiO₂, Na, K, Fe, Mn, and Ba were added to seawater. pH rose approximately 6. Glass reacted more extensively than diabase at 150°C. Major alteration product was smectite.

201. A) Gen. Cat.--Hydrothermal alteration

B) Shvedenkov, G. Y.; Zubkov, M. Y.; Shvedenkova, S. V.; Bogdanova, V. I.,
1979, Interaction kinetics in the solvus range for K-Na feldspars under
hydrothermal conditions: *Geochemistry International*, v. 16, no. 6,
p. 135-143.

C) Purpose: examine changes in feldspar and solution during their reaction.

Methods: flame photometry

Results: alteration of feldspar is rapid during first 10 hours, followed
by an asymptotic approach to equilibrium. Data indicate a rapid transfer
from external to internal diffusion during interaction. As a result,
natural feldspars always have properties dependent on solid state
diffusion.

202. A) Gen. Cat.--Alteration studies or Diagenesis

B) Tourtelot, H. A., 1979, Black shale - its deposition and diagenesis: Clays and Clay Minerals, v. 27, no. 5, p. 313-321.

C) Purpose: summarize data on study and interpretation of black shale sequences.

Methods: literature review.

Results: near surface diagenesis is restricted to sulfate reduction and deposition of sulfide minerals. At greater depths, fermentation results in biogenic methane, followed by decarboxylation reactions and thermal maturation that form additional hydrocarbons at successively greater depths.

203 . A) Gen. Cat.--Hydrothermal alteration and clay behavior

B) Alderton, D. H. M.; Pearce, J. A.; Potts, P. J., 1980, Rare earth element mobility during granite alteration: Evidence from southwest England: Earth and Planetary Science Letters, v. 49, p. 149-165.

C) Purpose: to evaluate chemical changes in granitic rocks that have reacted with fluids, hydrothermal or supergene.

Methods: minerals were separated by electromagnetic and heavy liquid techniques and REE was measured by instrumental neutron activation analysis.

Results: REE were found to be potentially mobile during hydrothermal and supergene alteration. Trivalent REE were removed from the system during K-silicate alteration, Eu was lost during sericitic alteration, all REE were lost during tourmalinization, and light REE were lost during chloritization and argillic alteration. The fluids themselves had low REE concentrations; in only one case (chloritization) were heavy REE introduced during alteration. Analysis of separated minerals indicates that the behavior of the REE could be partly explained in terms of their different affinities for the primary and secondary assemblages. Thermodynamic calculations indicated that REE mobility is enhanced by the presence of fluorine in the alteration fluids partly because REE forms more stable complexes with F than with Cl and partly because elements such as Ti, Zr, and P that form REE-bearing minor phases are themselves potentially mobile.

204 . A) Gen. Cat.--Hydrothermal alteration

B) Dikin, A. P.; Exley, R. A.; Smith, B. M., 1980, Isotopic measurements of Sr and O exchange between meteoric-hydrothermal fluid and the Coire Uaigneich granophyre, Isle of Skye, N. W. Scotland: Earth and Planetary Science Letters, v. 51, p. 58-70.

C) Purpose: to determine the scale and magnitude of hydrothermal Sr contamination in an ^{18}O -depleted granite from the Isle of Skye.

Methods: Sr and O isotope and electron microprobe mineral analysis were performed on samples of Coire Uaigneich granophyre including 2 samples cut by mineralized fractures.

Results: unfractured whole rock initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios are between 0.7298-0.7320 and $\delta^{18}\text{O}$ are $\pm 2\%$ of SMOW. Most severe ^{18}O depletions are found next to contact zones, due to structural control of fluid flux and vigorous O exchange with the fluids. $^{87}\text{Sr}/^{86}\text{Sr}$ ratios do not correlate with $\delta^{18}\text{O}$ values, probably because of low fluid Sr content. Sr isotope gradients exist in fracture zones containing epidote, chlorite and albitized plagioclase. This suggests enhanced but localized Sr exchange during mineral reactions of temperatures around 400°C . Final fluids to circulate precipitate epidote, which plugged the fractures. Mn and Sr zoning in the epidotes reflects changes in the Sr isotope and trace element chemistries of the late fluids and increased buffering of the fluids by the host rock.

205 . A) Gen. Cat.--Hydrothermal alteration

B) Dowsett, F. R., 1980, Hydrothermal alteration of the Hahns Peak Stock,
Routl County, Colorado: Economic Geology, v. 75, no. 1, p. 30-44.

C) Purpose: to study the hydrothermal alteration of the Hahns Peak Stock,
in order to test the utility of structural state and composition of
alkali feldspars as guides to conditions in hydrothermal systems.

Methods: geologic mapping, petrography, XRD.

Results: hydrothermal alteration and mineralization took place in
two separate stages. The first produced pervasive albitic alteration
in a temperature range of 400 to 500°C. The second was strongly
localized along fracture and breccia zones, and took place in the
temperature range 250 to 350°C. Detailed data on feldspars was
useful in distinguishing alkali feldspars of alteration origin from
those of igneous origin.

206 . A) Gen. Cat.--hydrothermal alteration

B) Exley, R. A., 1980, Microprobe studies of REE-rich accessory minerals:

Implications for Skye granite petrogenesis and REE mobility in hydrothermal systems: Earth and Planetary Science Letters, v. 48, p. 97-110.

C) Purpose: REE behavior studies in different media.

Methods: microprobe analysis.

Results: hydrothermal allanites in altered Tertiary igneous rocks from Skye ore. LREE enriched while allanites from altered Torridonian arkoses have less fractionated REE patterns, because the instability of metamict HREE-rich detrital zircons buffered the hydrothermal solutions to more HREE-rich compositions. Zoning in the hydrothermal allanites suggests evolution of the parent fluids to more HREE rich during allanite growth.

207 . A) Gen. Cat.--Hydrothermal alteration

B) Laznicka, P.; Edwards, R. J., 1980, Dolores Creek, Yukon - a disseminated copper mineralization in sodic metasomatites: *Economic Geology*, v. 74, no. 6, p. 1352-1370.

C) Purpose: to describe the geology and mineralization at Dolores Creek.

Methods: surface mapping, examination of drill core, petrography, XRD, XRF, AA, INAA.

Results: the Dolores Creek albitic rocks are considered to be metasomatic albitites. Diorite dikes at Dolores Creek are considered to be the carriers of copper and cobalt, and these metals migrate during the course of alteration.

208. A) Gen. Cat.--hydrothermal alteration

B) McCulloch, M. T.; Gregory, R. T.; Wasserburg, G. J.; Taylor, H. P., Jr.,
1980, A neodymium, strontium, and oxygen isotopic study of the
Cretaceous Samail ophiolite and implications for the petrogenesis
and seawater-hydrothermal alteration of oceanic crust: Earth
and Planetary Science Letters, v. 46, p. 201-211.

C) Purpose: to distinguish between sea floor hydrothermal alteration
and primary magmatic processes.

Methods: analysis of ^{147}Sm - ^{143}Nd , ^{87}Rb - ^{87}Sr and $^{18}\text{O}/^{16}\text{O}$ isotopic
systems in the Samail ophiolite.

Results: Rb-Sr and $^{18}\text{O}/^{16}\text{O}$ exhibit sensitivity to hydrothermal
interactions with seawater while the Sm-Nd stays undisturbed.

The $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{18}\text{O}$ values have large variations across the
ophiolite and are consistent with hydrothermal interaction of seawater
with the crust. A model is presented for the closed system exchange
of Sr and O that in principle illustrates how the Sr isotopic data
may be utilized to estimate the water/rock ratio and subsequently
used to evaluate the temperature of equilibration between the water
and silicates from the $^{18}\text{O}/^{16}\text{O}$ water rock fractionation.

209 . A) Gen. Cat.--Alteration studies

B) Nesbitt, H. W., 1980, Characterization of mineral-formation water interaction in Carboniferous sandstones and shales of the Illinois sedimentary basin: American Journal of Science, v. 280, no. 7, p. 607-630.

C) Purpose: identify important mineral-solution interactions in the Illinois Basin.

Methods: petrography, wet chemical analysis.

Results: The waters are undersaturated with respect to halite, anhydrite, feldspars, biotite, chlorite, CaMg-rich clay minerals, and gibbsite, but are in equilibrium with kaolinite, illite, calcite and a Na-clay. Concentrations of SO_4 and CO_3 vary greatly. Solutions are in equilibrium with illite and kaolinite, as opposed to feldspars, due to the greater abundance of the clays. Water-clay interactions control Na^+/H^+ . Na^+ depletion is due to solution-mineral interactions rather than passage of a sodium complex through shale "membranes."

210 . A) Gen. Cat.--Alteration

B) Riverin, G.; Hodgson, C. J., 1980, Wall-rock alteration of the Millenbach

Cu-Zn Mine, Noranda, Quebec: Economic Geology, v. 75, no. 3, p. 424-444.

C) Purpose: to map in underground exposures and drill core the distribution of alteration types, then to characterize the map units mineralogically and chemically by a study of selected specimens.

Methods: chemical analyses, petrography.

Results: 1) Post-ore metamorphism has not significantly affected the composition of the rocks. 2) Chemical and mineralogical zonations on the scale of the alteration pipes as a whole and within vein selvages are similar. 3) Alteration reactions, which occurred at alteration zone boundaries, have been defined on the assumption that alteration took place at a constant volume of solid phases. 4) The distinctive pattern of progressive chemical change of the rocks which has resulted from their progressive reactions with the fluids could be used in mineral exploration as a geochemical criteria for alteration of the type associated with massive sulfide deposits.

211 . A) Gen. Cat.--Alteration studies

B) Seyfried, W. E., Jr.; Dibble, W. E., Jr., 1980, Seawater-peridotite interaction at 300°C and 500 bars: implications for the origin of oceanic serpentinites: *Geochimica et Cosmochimica Acta*, v. 44, no. 2, p. 309-321.

C) Purpose: determine chemical exchanges, path and mechanism of secondary mineral formation when peridotite and sea water react.

Methods: plasma emission, chemical analyses, AAS, XRD.

Results: Mg, Ca, Sr, SO₄, and H₂O were removed from seawater; H₂S, Zn, Fe, and Mn were added. B content was constant until temperature was dropped, after the experiment, when it decreased, suggesting that B in serpentinites is the result of a post-serpentinization alteration. The final assemblage generated is consistent with calculated expectations and field observations.

212 . A) Gen. Cat.--Hydrothermal alteration

B) Zugorskiy, V. Y.; Makagon, V. M., 1980, Petrochemical features of metasomatism in the exocontacts of rare-metal pegmatites: *Geochemistry International*, v. 17, no. 4, p. 73-79.

C) Purpose: present data on the petrochemistry of exocontact processes.

Methods: petrography, microprobe.

Results: all the metasomatites show loss of Ca and Na, with influx of K, rare alkalis, and volatiles. The alkalis and volatiles control the type of metasomatism: alkali metasomatism with high fluorine activity results in lithian micas, holmquistite and biotite form if fluorine activity is low. Rare alkalis occur at high concentrations and act as petrogenetic elements in some types of exocontact rock.

213 . A) Gen. Cat.--Hydrothermal alteration

B) Bargar, K. E.; Beeson, M. H., 1981, Hydrothermal alteration in research drill hole Y-2, Lower Geyser Basin, Yellowstone National Park, Wyoming: American Mineralogist, v. 66, no. 5 and 6, p. 473-490.

C) Purpose: to describe the alteration in the Y-2 drill hole.

Methods: petrography, chemical analyses, electron microprobe, SEM, XRD.

Results: alteration of zones of calcium-rich and sodium- and potassium-rich hydrothermal minerals suggests that the water chemistry in this drill hole varies with depth.

214 . A) Gen. Cat.--Hydrothermal alteration

B) Chiba, H.; Kusakabe, M.; Hirano, S.; Natsuo, S.; Shigeyuki, S., 1981,
Oxygen isotope fractionation factors between anhydrite and water
from 100 to 550°C: Earth and Planetary Science Letters, v. 53,
p. 55-62.

C) Purpose: to analyze fractionation factors of O isotopes between anhydrite
and water.

Methods: partial equilibrium techniques.

Results: the exchange rate was low in the NaCl solution. In the lower-
temperature range, acid solutions produced sufficient reaction to determine
the oxygen isotope fractionation factors. The temperature dependence of
the O isotope fractionation factors was calculated by the least squares
method in which the weight was taken to be inversely proportional to
the experimental error. The fractionation is given by :

$$10^3 \ln \alpha_{\text{anhydrite}} = 3.21 \times (10^3/T)^2 - 4.72. \quad \alpha = \text{fractionation factor}$$

Available $\delta^{18}\text{O}$ values of natural anhydrite were used to test the validity
of this expression with good results.

215. A) Gen. Cat.--Hydrothermal alteration

B) Coveney, R. M., Jr., 1981, Gold quartz veins and auriferous granite at the Oriental Mine, Alleghany District, California: Economic Geology, v. 76, no. 8, p. 2176-2199.

C) Purpose: to present data on the geothermometry, mineralogy, paragenetic relations, and origins of the vein and alteration assemblages of the Oriental Mine.

Methods: electron microprobe, XRD, petrography, chemical analyses (wet chemistry, fire assay), fluid inclusions.

Results: The Oriental Mine gold veins were deposited in the temperature range of approximately 200° to 300°C, at pressures between 670 and 2500 bars, and at depths in excess of 2.5 km. During the early stages of mineralization, temperatures probably exceeded 340°C and may have been as high as 491°C.

216 . A) Gen. Cat.--Alteration studies

B) Dibble, W. E., Jr.; Tiller, W. A., 1981, Non-equilibrium water/rock interactions - I. Model for interface controlled reactions: *Geochimica et Cosmochimica Acta*, v. 45, no. 1, p. 79-92.

C) Purpose: develop a new model for mineral/water reactions controlled by surface processes.

Methods: calculations based on previously reported data.

Results: overall reaction rate at steady-state is determined by coupling equations for the velocities of mass transport and interface detachment processes. Non-steady state situation can be modelled if interface reactions control the rate. Linear rate laws apply when uniform detachment or layer-source generation mechanisms control the dissolution rate. First order or logarithmic rate laws should prevail if low interfacial undersaturations exist. Parabolic time dependence results if one of several parameters is a function of time^{1/2}.

217. A) Gen. Cat.--Alteration studies or Behavior of trace elements in geomedial
- B) Elderfield, H.; McCaffrey, R.J.; Luedtke, N.; Bender, M.; Truesdale, V.W.,
1981, Chemical diagenesis in Naragansett Bay sediment: American
Journal of Science, v. 281, no. 8, p. 1021-1055.
- C) Purpose: present comprehensive interstitial water and benthic flux data
for anoxic sediments in Naragansett Bay.
- Methods: gas chromatography, AAS, wet chemical analysis.
- Results: total CO_2 and NH_3 increase with depth except when removed by
macro infauna. In some cases, sulfate is reduced by CH_4 . ΣI increases
with depth and correlates strongly with ΣCO_2 , reflecting its biophilic
nature. Solubility of Mn is controlled by the system Mn-Ca- CO_3 ; that of
Fe is controlled by sulfides. Concentrations of Ni, Cd, and Cu are
undetectable or decrease with depth due to precipitation of sulfides.

218 . A) Gen. Cat.--Hydrothermal alteration

B) Fanning, K. A.; Byrne, R. H.; Breland, J. A., II; Betzer, P. R., 1981, Geothermal springs of the West Florida continental shelf: Evidence for dolomitization and radionuclide enrichment: Earth and Planetary Science Letters, v. 52, p. 345-354.

C) Purpose: to analyze hot springs found off the coast of western Florida.

Methods: 1) sonic depth profiling, 2) looking for turbid plumes in overlying water, 3) side-scan sonar, 4) looking for sea turtles since they were found only around the vents. Chemical and radiochemical analysis were made.

Results: seawater percolates down from the ocean bottom to about 500-1000 meters below sealevel where it is heated to about 40°C and altered. It then rises and is discharged into the ocean. While underground the water causes secondary dolomitization of the limestones because the discharged seawater is lower in Mg and higher in Ca than normal. The spring water is also enriched 1000 times in ^{226}Ra , 10,000 times in ^{222}Rn , and 90 times in ^{228}Ra compared to surrounding seawater. The percolating seawater also loses all of its oxygen and nitrate to reducing processes, loses most of its phosphate and 40% of its ^{238}U and almost quadruples its silica.

- 219 . A) Gen. Cat.--Alteration studies or Behavior of trace elements in geomedial
- B) Komarneni, S.; White, W. B., 1981, Hydrothermal reactions of clay minerals and shales with cesium phases from spent fuel elements: Clays and Clay Minerals, v. 29, no. 4, p. 299-308.
- C) Purpose: examine immobilization of Cs by clays under hydrothermal conditions.
Methods: XRD, ASS.
Results: reaction of Cs with clay minerals for up to 4 months yields pollucite as the principal product, along with CsAlSiO_4 and hydrothermally altered alumino-silicates. Fixation of as much as 97% of added Cs was observed. Cs was fixed on cation-exchange sites by interlayer collapse in montmorillonite. U^{6+} from added $\beta\text{-Cs}_2\text{U}_2\text{O}_7$ was reduced to uraninite by sulfide- or organic-rich shales.

220 . A) Gen. Cat.--Alteration studies

B) Moncure, G. K.; Surdam, R. C.; McKague, H. L.; 1981, Zeolite diagenesis below Pahute Mesa, Nevada Test Site: Clays and Clay Minerals, v. 29, no. 5, p. 385-396.

C) Purpose: examine a geologic setting undergoing diagenesis.

Methods: XRD, AAS, microprobe, wet chemical methods.

Results: the silicic volcanic rocks at Pahute Mesa are divided into 3 diagenetic zones: 1) Zone 1 is uppermost and contains unaltered or slightly altered rhyolitic glass; 2) Zone 2 contains predominantly clinoptilolite and minor smectite, cristobalite, and mordenite; 3) Zone 3 includes analcime, quartz, calcite, authigenic Na and K feldspar, kaolinite, chlorite and mixed illite/smectite. Formation of Zone 2 by reaction with interstitial water resulted in a net porosity loss and negligible mass transfer. Dehydration of the Zone 2 assemblage with deep burial resulted in an increase in porosity and permeability and formation of the Zone 3 assemblage.

221 . A) Gen. Cat.--Geothermal effects

B) Nagao, K.; Takaoka, N.; Matsubayashi, O., 1981, Rare gas isotopic composition in natural gases of Japan: Earth and Planetary Science Letters, v. 53, p. 175-188.

C) Purpose: to investigate rare gas isotope compositions of terrestrial rare gases of Japan.

Methods: samples were analyzed by mass spectrometry.

Results: Excess ^3He was found in most samples compared to atmospheric norms. Many samples showed a regional uniform high $^3\text{He}/^4\text{He}$ ratio of 7 times the atmospheric ratio. The samples were low in CO_2 -rich gases and high in N_2 rich gases. Ne isotopes deviated from the atmosphere Ne. Deviations and elemental abundance patterns are explained by mixing of mass fractionated rare gases and heavy rare gas atmospheric isotope. Example: Ar was a mix of mass fractionated Ar, atmospheric Ar and radiogenic Ar (this contribution was small). Except for He, samples were enriched in heavy rare gases relative to the atmosphere. Some samples were heavily enriched in Kr and Xe. The component highly enriched in heavy, rare gases may be released from sedimentary materials in the crust.

222 . A) Gen. Cat.—Hydrothermal alteration

B) Parry, S.; Hutchinson, R. W., 1981, Origin of a complex alteration assemblage, Four Corners Cu-Zn Prospect, Quebec, Canada: Economic Geology, v. 76, no. 5, p. 1186-1201.

C) Purpose: to study three types of hydrothermal alteration spatially associated with Cu-Zn mineralization within the Archean Blake River Group of greenschist facies metavolcanic rocks, Naranda, Quebec.

Methods: petrography, field mapping.

Results: textural and geochemical evidence and similarities with presently active geothermal systems indicate alteration and mineralization were products of an Archean convective system, closely related in time and space to volcanism.

223 . A) Gen. Cat.--Alteration studies

B) Ratterman, N. G.; Surdam, R. C., 1981, Zeolite mineral reactions in a tuff in the Laney Member of the Green River Formation, Wyoming: Clays and Clay Minerals, v. 29, no. 5, p. 365-377.

C) Purpose: delineate the diagenetic history of a tuff bed.

Methods: XRD, AAS, SEM.

Results: 2 diagenetic events occurred, both at less than 100°C. The first event involved reaction of glass with saline, alkaline solutions and precipitation of zeolites. Variation in zeolite mineralogy is due to differences in interstitial fluid chemistry. The second event resulted in the production of analcime as early formed zeolites reacted with upward moving sodium carbonate brines.

224. A) Gen. Cat.--Hydrothermal alteration

B) Ryzhenko, B. N.; Mel'nikova, G. L.; Shvarov, Y. V., 1981, Computer modelling of formation of the chemical composition of natural solutions during interaction in the water-rock system: *Geochemistry International*, v. 18, no. 2, p. 94-108.

C) Purpose: calculate composition of a fluid in equilibrium with a sediment of granitic and basaltic composition at temperatures from 25°-300°C.

Methods: computer modelling.

Results: the following features characterize, in part, the formation of the aqueous phase: 1) Enrichment with alkalis, and an increase in Na/K, in the solution with a decrease in temperature or increase in rock/water ratio; 2) Appearance of alkaline earths in solution as a result of mineralization by anionogenic elements; 3) Predominance of Na, Mg, Ca, Cl, S⁶⁺ and C⁴⁺ under surface conditions, and Na, Ca, K, Cl, C⁴⁺ and Si under high temperature conditions, in the aqueous phase.

225 . A) Gen. Cat.--Alteration studies

B) Seyfried, W. E. , Jr.; Bischoff, J. L., 1981, Experimental seawater - basalt interaction at 300°C, 500 bars, chemical exchange, secondary mineral formation and implications for the transport of heavy metals: *Geochimica et Cosmochimica Acta*, v. 45, no. 2, p. 135-147.

C) Purpose: develop a general model for element exchange under the experimental conditions, ascertain the degree to which heavy metals and H₂S enter seawater, compare observed alteration products to natural systems.

Methods: rock/water interactions were carried out for between 600 and 2208 hours. Results were analyzed by chemical analysis, XRD, AAS, and microprobe.

Results: seawater increased in almost all metals, H₂S, CO₂, and H⁺; it decreased in SO₄ and Mn. Basalt glass was completely replaced by clays, zeolites, anhydrite and hematite; diabase was partially replaced by clays, anhydrite and magnetite. Heavy metals were not solubilized in 0.45M NaCl solution, thus the removal of Mg from seawater and resultant drop in pH are responsible for heavy metal solubility in seawater.

226. A) Gen. Cat.--Alteration of basalt

B) Shanks, W. C., III; Bischoff, J. L.; Rosenbauer, R. J., 1981, Seawater sulfate reduction and sulphur isotope fractionation in basaltic systems: Interaction of seawater with fayalite and magnetite at 200-350°C: *Geochimica et Cosmochimica Acta*, v. 45, no. 11, p. 1977-1995.

C) Purpose: define conditions of sulphate reduction and monitor sulphur species and isotopes in experiments that model hydrothermal seawater interaction with basalt.

Methods: petrography, AAS, colorimetry, chloridometry, electrode techniques, infrared analyzer, gravimetry, gamma counting, XRD, SEM, mass spectrometry.

Results: sulphate reduction was rapid at 350°C. At 250°C, H₂S was detected but was minor. At 200°C, no H₂S was detected, although pyrite may have formed. Isotopic equilibrium is reached at T = 250°-350°C. Isotopic composition of the H₂S was strongly dependent on water/rock ratios. Precipitation of anhydrite prevents entry of sulfate into high T interaction zones.

227. A) Gen. Cat.--Hydrothermal alteration

B) Steinthorsson, S.; Sveinbjörnsdóttir, A. E., 1981, Opaque minerals in geothermal well No. 7, Krafa, northern Iceland: Journal of Volcanology and Geothermal Research, v. 10, p. 245-261.

C) Purpose: to shed light on the processes affecting the precipitation of the mineral assemblages studied here.

Methods: analysis of minerals by electron microprobe and other chemical means. Thermo-chemical calculations were also made.

Results: mineral assemblages formed by precipitation from hydrothermal fluids is described. Processes for the deposition of the minerals is discussed.

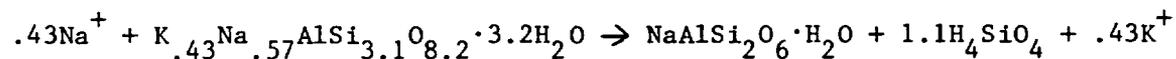
228. A) Gen. Cat.--Alteration studies

B) Taylor, M. W.; Surdam, R. C., 1981, Zeolite reactions in the tuffaceous sediments at Teels Marsh, Nevada: Clays and Clay Minerals, v. 29, no. 5, p. 341-352.

C) Purpose: understand reactions that can occur between volcanic glass and saline, alkaline solutions.

Methods: XRD, AAS, colorimetry, XRF, wet chemical methods.

Results: hydration of rhyolite glass by interstitial brines forms phillipsite, with a hydrous alkali alumino-silicate gel as an intermediate product. Reaction of Na^+ with phillipsite can form analcime, while releasing K^+ and silica into solution:



The equilibrium constant for this reaction is 3.04×10^{-5} . At 25°C and 1 atm, $\Delta G_R^\circ = +6.2$ kcal/mol; ΔG_f° for phillipsite is -1072.8 kcal/mol.

229. A) Gen. Cat.--Hydrothermal systems

B) Barsukov, V. L.; Borisov, M. V., 1982, Simulation of the geochemical consequences of auto-mixing of hydrothermal solution. Part I. Mass transfer in areas of spreading of hydrothermal solutions: Geochemistry International, v. 19, no. 4, p. 137-150.

C) Purpose: examine auto-mixing using an artificial simplified geologic example.

Methods: calculations based on published data.

Results: automixing inevitably results in 3 products: 1) metasomatized wall rock; 2) solution that has not reacted and has virtually its same original composition; 3) solution that has reacted with wall rock and has a new composition. The 2 solutions react when they come into contact.

230. A) Gen. Cat.--Hydrothermal alteration

B) Bychkov, A. M.; Kotel'nikov, A. R., 1982, The structural transitions in plagioclases under hydrothermal conditions: *Geochemistry International*, v. 19, no. 4, p. 99-101.

C) Purpose: examine plagioclase structure in ion-exchange experiments.

Methods: XRD.

Results: ion exchange between plagioclase and fluid occurred within a few days. Products were substantially disordered and close to high plagioclase.

231. A) Gen. Cat.--Alteration studies or Hydrothermal systems

B) Franz, G.; 1982, The brucite-periclase equilibrium at reduced H₂O activities: some information about the system H₂O-NaCl: American Journal of Science, v. 282, no. 8, p. 1325-1339.

C) Purpose: obtain data on brucite-periclase equilibrium and the H₂O-NaCl system.

Methods: petrography.

Results: assuming ideal mixing of NaCl and H₂O, the observed temperature decrease for the breakdown of brucite correlates well with calculated temperatures. Fugacity of H₂O in the NaCl solution ranges from 620 bars at 590°C to 1259 bars at 670°C; H₂O activity ranges from .611 at 590°C to 1.000 at 670°C.

232. A) Gen. Cat.--Alteration studies

B) Glasmann, J. R., 1982, Alteration of andesite in wet, unstable soils of Oregon's Western Cascades: Clays and Clay Minerals, v. 30, no. 4, p. 253-263.

C) Purpose: describe weathering of andesitic clasts in soils in the Cascade Mountains.

Methods: petrography, SEM, XRD, thermal techniques.

Results: augite phenocrysts altered by congruent dissolution leaving voids which were subsequently filled with smectite. Plagioclase altered to micrometer-sized aggregates of smectite. Formation of smectite was probably favored by the restricted drainage and wet soil conditions.

233. A) Gen. Cat.--Hydrothermal alteration

B) Gunnlaugsson, E.; Arnorsson, S., 1982, The chemistry of iron in geothermal systems in Iceland: Journal of Volcanology and Geothermal Research, v. 14, p. 281-299.

C) Purpose: to study iron distribution in thermal waters of Iceland.

Methods: precipitation of iron followed by x-ray fluorescence analysis for concentrations of iron.

Results: iron phases are given for different temperatures of water.

234. A) Gen. Cat.--Hydrothermal alteration

B) Jones, A. P.; Smith, J. V.; Dawson, J. B., 1982, Mantle metasomatism in 14 veined peridotites from Bultfontein Mine, South Africa: *Journal of Geology*, v. 90, no. 4, p. 435-454.

C) Purpose: examine changes in peridotite xenoliths due to metasomatism.

Methods: petrography, microprobe.

Results: 13 xenoliths show recrystallization zones and coarse veins containing mica, amphibole, and diopside, and trace-element rich titanate, Cr-spinel and Mg-ilmenite. Overall mineralogy suggests a genetic relationship to the MARID suite (mica, amphibole, rutile, ilmenite, and diopside), but micas and amphiboles of the 2 assemblages do not overlap in composition. It is possible that the peridotites reacted with 2 liquids, one of which later gave rise to MARID pegmatites. Depth of crystallization of peridotite is less than 100 km, based on presence of K-richterite.

A) Gen. Cat.--Hydrothermal alteration

B) Kaminen, D. C.; Dugal, J. J. B., 1982, A study of rock alteration in the Eye-Dashwa lakes pluton, Atikokan, northwestern Ontario, Canada. In: G. W. Bird and W. S. Fyfe (Editors), Geochemistry of Radioactive Waste Disposal. Chemical Geology, v. 36, no. 1/2, p. 35-57.

C) Purpose: to discuss megascopic, microscopic, and geochemical characteristics of the drill core and the significance of rock alteration as pertains to the disposal of nuclear waste in crystalline rock.

Methods: petrography, chemical analyses (AA, XRF), porosity and permeability measurements, electron microprobe.

Results: chemically, altered rocks show: 1) loss of Ca and Sr; 2) gain of Mg; 3) higher oxidation ratios. Pore water collected at 500m and below from ATK-1 borehole shows an increase of Ca and Sr and decrease of Mg. This suggests that deep pore water evolved through rock alteration followed by equilibration with the host-rock, with insignificant dilution by water from shallow depths. Thus, it appears that if the vault for nuclear fuel waste is located in crystalline rock at 1 km depth, it would be an environment of groundwater isolated from the biosphere. In addition, altered rocks have lower porosity and permeability, and higher sorption capacity, than unaltered rocks.

236 . A) Gen. Cat.--Alteration

B) London, D.; Burt, D. M., 1982, Alteration of spodumene, montebrasite, and lithiophilite in pematites of the White Picacho District, Arizona: American Mineralogist, v. 67, no. 1 and 2, p. 97-113.

C) Purpose: to describe the mineralogy of replacement assemblages observed in primary spodumene, montebrasite, and lithiophilite from the White Picacho pegmatites.

Methods: petrography, electron microprobe, XRD.

Results: subsolidus metasomatic alteration of spodumene, montebrasite, and lithiophilite was pseudomorphic in nature and produced a large number of fine-grained secondary phases and replacement assemblages.

237. A) Gen. Cat.--Alteration, hydrothermal

B) Plimer, I. R.; de Carvalho, D., 1982, The geochemistry of hydrothermal alteration at the Salgadinho copper deposit, Portugal: *Mineralium Deposita*, v. 17, no. 2, p. 193-211.

C) Purpose: to document a new type of deposit in the Iberian Pyrite Belt and to describe the associated hydrothermal alteration.

Methods: petrography, XRD, infrared spectrometry, chemical analyses (XRF)

Results: alteration of feldspars and groundmass has involved a net loss from the system and garns in Fe^{2+} , F, H_2O , Mg, Fe^{3+} , Ca, Mn, P, Ti, S, Cu, Zn, Pb, As, Sb, Ag, and Au at the expense of Si, K, Al, and Na.

238 . A) Gen. Cat.--Alteration studies or Metamorphism

B) Rumble, D., III; Ferry, J. M.; Hoering, T. C.; Boncrot, A. J., 1982, Fluid flow during metamorphism at the Beaver Brook fossil locality, New Hampshire: American Journal of Science, v. 282, no. 6, p. 886-919.

C) Purpose: examine evidence for fluid flow of Beaver Brook.

Methods: petrography, microprobe, mass spectrometry.

Results: metamorphism occurred with $T = 600^{\circ}\text{C}$ and $P = 3.5$ kbar. Fluids were water rich ($X_{\text{H}_2\text{O}} = 0.80$) with variable amounts of CO_2 and CH_4 . Fluid/rock ratios range from 1.5 to 4.0, based on mineralogical evidence, and 4.0 to 6.0, based on isotopic evidence. The large volume of fluid flow is attributed to decarbonation reactions, which enhance permeability.

239 . A) Gen. Cat.--Hydrothermal alteration

B) Zharikov, V. A., 1982, Physicochemical studies of wall-rock metasomatism:

Geochemistry International, v. 19, no. 6, p. 124-150.

C) Purpose: evaluate data and methods used in the study of wall-rock metasomatism.

Methods: literature review.

Results: quantitative characterization of the physicochemical conditions for the production of metasomatite associations is an unsolved problem, although solution should be just a matter of time. New developments will allow the use of metasomatites for genetic, prospecting, and surveying purposes.

240 . A) Gen. Cat.--Hydrothermal alteration

B) Brimhall, G. H., Jr.; Ghiorso, M. S., 1983, Origin and ore-forming consequences of the advanced argillic alteration process in hypogene environments by magmatic gas contamination of meteoric fluids: Economic Geology, v. 78, no. 1, p. 73-90.

C) Purpose: to examine possible origins for advanced argillic wall-rock alteration.

Methods: simulated irreversible chemical reactions using the approach of Helgeson (1968, 1971), computer programs (EQ3-EQ6) of Wolery (1979), and the thermodynamic data base of Helgeson et. al. (1978) and Wolery (1979).

Results: Establishes a definite genetic relationship between the advanced argillic alteration assemblage and a number of important physical and chemical parameters which undergo extreme behavior at this crucial stage of geochemical evolution. Suggests that the advanced argillic assemblage represents a critical transition state or threshold, which if attained in a given hydrothermal system creates a very special environment of greatly enhanced fluid flow, alteration, and ore deposition, including chemical mechanisms for self-sealing and ore preservation.

241 . A) Gen. Cat.--Hydrothermal alteration

B) Crowley, J. C.; Gillitti, B. J., 1983, Patterns of oxygen isotope depletion, multiple hydrothermal circulation systems, and the cooling history of the Stony Mountain intrusive complex, Colorado : Earth and Planetary Science Letters, v. 64, p. 231-243.

C) Purpose: using oxygen isotope data to determine hydrothermal systems and cooling history of the Stony Mt. complex.

Methods: O isotope compositions of 27 whole rock and mineral samples from the three intrusive phases of the Stony Mt. complex were measured and are combined with other published analysis.

Results: ^{18}O is significantly depleted relative to normal igneous rocks in all three intrusive phases. It is determined that this occurred as a subsolidus exchange of O isotopes. The complex depletion patterns suggest separate hydrothermal systems cooled the complex. Water/rock ratios and temperature determinations are made.

242 . A) Gen. Cat.--Hydrothermal alteration, element mobility

B) Dickin, A. P.; Jones, N. W., 1983, Relative elemental mobility during hydrothermal alteration of a basic sill, Isle of Skye, N.W. Scotland: Contributions to Mineralogy and Petrology, v. 82, no. 2 and 3, p. 147-153.

C) Purpose: to make a detailed comparison of major, trace element, and isotopic disturbances in basic rock adjacent to a major hydrothermal conduit, in order to determine the relative inability of a large number of different elements during the meteoric-hydrothermal alteration process.

Methods: petrography, Pb, Rb, Cs, Sr, Pb, Ca and Na is explained by the differing ease with which they could be incorporated into a new albite-calcite-chlorite-epidote mineralogy. The constitution of this hydrothermal mineralogy was largely determined by the primary igneous mineralogy, though the composition of hydrothermal fluids had a subordinate influence.

243 . A) Gen. Cat.--Alteration studies

B) Evarts, R. C.; Schiffman, D., 1983, Submarine hydrothermal metamorphism of the Del Puerto ophiolite, California: American Journal of Science, v. 283, no. 4, p. 289-340.

C) Purpose: report on the metamorphism of the Del Puerto ophiolite.

Methods: petrography, electron microprobe.

Results: the entire ophiolite is characterized by a metamorphic zonation increasing in grade downward. Zones are delineated by zeolites, pumpellyite and epidote. Chemistry and mineral assemblages indicate interaction between volcanic rocks and convecting seawater, with a T gradient $\gt 100^{\circ}\text{C} / \text{km}$. Alteration below dike and sill complex is minimal. Subsequent burial by $\lt 10$ km of ferrigenous sediments did not have a great effect. Lack of massive sulfides may indicate high f_{O_2} in fluid phase.

244. A) Gen. Cat.--Alteration studies in salt

B) Fournier, R. O., 1983, A method of calculating quartz solubilities in aqueous sodium chloride solutions: *Geochimica et Cosmochimica Acta*, v. 47, no. 3, p. 579-586.

C) Purpose: develop a model for calculating the effect of NaCl on quartz solubility over a range of T's and P's without using water fugacity and osmotic coefficient information for NaCl solutions.

Methods: use of existing published data to derive equations.

Results: solubility of quartz in NaCl solutions can be calculated by:

$$\log m_s = \log K + n \log p_e - \log \gamma_s + \log \Gamma^*$$

where: m_s = molality of aqueous silica

n = aqueous silica hydration number (average number of water molecules complexed onto a single SiO_2)

p_e = effective density of water in saline solution

γ_s = molal activity coefficient of aqueous silica

Γ^* = factor expressing the product of coefficients of changes in activity with pressure of water and quartz, divided by that of aqueous silica.

Data suggest that at 350°C , H_4SiO_4 may be the dominant aqueous silica species in equilibrium with quartz, but other forms become important at $T < 350^\circ\text{C}$.

245. A) Gen. Cat.--Alteration studies in salt

B) Fournier, R. O.; Marshall, W. L., 1983, Calculation of amorphous silica solubilities at 25° to 300°C and apparent cation hydration numbers in aqueous salt solutions using the concept of effective density of water: *Geochimica et Cosmochimica Acta*, v. 47, no. 3, p. 587-596.

C) Purpose: to show that the method developed in Fournier (1983) (previous listing) is compatible with previously published experimental data.

Methods: use of preexisting data.

Results: hydration of SiO_2 decreases with increasing T from an average of 5.4 molecules of water/ molecule SiO_2 at 100°C to 3.4 at 300°C, suggesting that several hydrated aqueous silica species exist. Using the effective density of water model, an activity coefficient can be formulated that is independent of T and exponentially related to the molality of Na_2SO_4 .

Solubility of SiO_2 in salt solution at 25°C is given by:

$$\log m_s = -2.69 + 1.84 \log pF$$

where: m_s = molality of silica in solution

p = density of saline solution (g/cm^3)

F = weight fraction of water.

246 . A) Gen. Cat.--Hydrothermal alteration

B) Gibson, H. L.; Watkinson, D. H.; Comba, C. D. A., 1983, Silicification: hydrothermal alteration in an Archean geothermal system within the Amulet Rhyolite formation: Economic Geology, v. 78, no. 5, p. 954-971.

C) Purpose: to demonstrate that the Amulet Rhyolite formation is composed of altered andesites.

Methods: geologic mapping, petrography, chemical analyses (XRF)

Results: it is concluded that silicified andesite of the upper Amulet Rhyolite formation is a product of extensive lateral regional geothermal alteration. Solutions that evolved from reactions during mottled alteration and silicification were not significantly nor directly involved in ore forming processes. On comparison of the chemistry of least altered, mottled, and silicified andesite, it is apparent that SiO_2 varies inversely with Fe_2O_3 , MgO , MnO , and TiO_2 .

247 . A) Gen. Cat.--Hydrothermal Alteration

B) Hall, B. V., 1983, Geochemistry of the alteration pipe at the Amulet Upper A deposit, Noranda, Quebec: Canadian Journal of Earth Sciences, v. 19, no. 11, p. 2060-2084.

C) Purpose: to conduct a systematic, quantitative chemical and mineralogical study of the pillow lavas within the alteration pipe of the Amulet Upper A deposit.

Methods: chemical analyses (AA), petrography.

Results: proceeding into the alteration pipe, CaO, Na₂O, Ba, Cr, Ni, and Sr were removed, Fe₂O_{3_T}, MgO, K₂O, H₂O⁺, S²⁻, Cd, Cu, Li, and Zn were added, and Al₂O₃, TiO₂, and V remained relatively constant.

248 . A) Gen. Cat.--Alteration studies or Sorption studies

B) Inoue, A., 1983, Potassium fixation by clay minerals during hydrothermal treatment: Clays and Clay Minerals, v. 31, no. 2, p. 81-91.

C) Purpose: determine the factors that control the amount of K fixed by clay minerals under hydrothermal conditions.

Methods: XRD.

Results: the amount of K fixed by clays generally increased with increasing T, pH, and K-concentration, and reached saturation in 5-6 days. The behavior of K-fixation was specific to each clay. 40% of montmorillonite transformed to illite at 300°C in a mixed cation system (Ca and K).

- 249 . A) Gen. Cat.--Hydrothermal alteration or Behavior of clays in geomedial.
- B) Inoue, A.; Utada, M., 1983, Further investigations of a conversion series of dioctahedral mica/smectites in the Shinzan hydrothermal alteration area, northeast Japan: Clays and Clay Minerals, v. 31, no. 6, p. 401-412.
- C) Purpose: compare mica/smectites formed by hydrothermal alteration of volcanic glass show discontinuous changes in degrees of ordering of interstratification. This differs from the behavior of mica/smectites during burial diagenesis which show a continuous change in ordering type, and from rectorite, which displays a constant expandability and ordering over a wide range of conditions. Data indicate that the hydrothermal mica/smectites fix K in interlayers in response to a steep geothermal gradient and migration of hydrothermal solutions.

250 . A) Gen. Cat.--Alteration studies

B) Johnston, J. H.; Lewis, D. G., 1983, A detailed study of the transformation of ferrihydrite to hematite in an aqueous medium at 92°C: *Geochimica et Cosmochimica Acta*, v. 47, no. 11, p. 1823-1831.

C) Purpose: determine role of ferrihydrite in formation of hematite and goethite and the mechanisms which are important in the production of these 3 materials.

Methods: Mossbauer spectroscopic, x-ray diffraction, electron microscope, computer fitting of data.

Results: ferrihydrite conversion to hematite is accomplished directly as ferrihydrite particles coalesce to form hematite platelets with increasing aging. Hematite platelets increase in size with time but magnetic structure is not fully developed. This could be explained by the formation of an extended ferrihydrite type structure which approximates an incompletely ordered hematite.

Ferrihydrite can be produced at $T = 20^{\circ}\text{C}$, but higher T promotes rate of formation and degree of crystallinity.

251 . A) Gen. Cat.--Hydrothermal alteration

B) Meyers, R. E.; Maclean, W. H., 1983, The Geology of the New Inscocopper deposit, Noranda district, Quebec: Canadian Journal of Earth Sciences, v. 20, no. 8, p. 1291-1304.

C) Purpose: to describe the ore, volcanic stratigraphy, wall rock alteration, and conditions that prevailed during ore deposition and subsequent structural, metamorphic, and erosional events.

Methods: geologic mapping, petrography, chemical analyses (XRF, INAA).

Results: There are a number of features which are atypical of most Noranda-type massive sulfide deposits: 1) the orebody is a pyrrhotite rich, chalcopyrite-bearing lense, enclosed in pillowed and volcanoclastic rocks; 2) rocks above and below the ore lense are altered in a more or less conformable zonal arrangement rather than as a typical cross-cutting alteration pipe below the ore 3) the lens contains interstratified siliceous ore; and 4) large portions of the massive ore are oxidized and pyritized.

252 . A) Gen. Cat.--Hydrothermal alteration

B) Preece, R.K. III; Beane, R. E.; 1983, Contrasting evolutions of hydrothermal alteration in quartz monzonite and quartz diorite wall rocks at the Sierrita porphyry copper deposit, Arizona: Economic Geology, v. 77, no. 7, p. 1621-1641.

C) Purpose: investigate changes in temperature and salinity of hydrothermal fluids during the evolution of porphyry copper-type mineralization and alteration, and to attempt to establish the temporal relationship between different sequences of mineral assemblages developed in rocks of contrasting lithology using fluid inclusion characteristics.

Methods: fluid inclusions, petrography.

Results: this study documents a history of more or less continuous temperature decrease from about 430°C to less than 200°C attended by repeated fracturing and veining at wall rocks.

253 . A) Gen. Cat.—Hydrothermal alteration

B) Rosenbauer, R. J.; Bischoff, J. L.; Radtke, A. S., 1983, Hydrothermal alteration of graywacke and basalt by 4 molal NaCl: *Economic Geology*, v. 78, no. 8, p. 1701-1710.

C) Purpose: to report the results of experimentally reacting basalt and graywacke with pure 4m NaCl.

Methods: chemical analyses

Results: 1. The 4 m NaCl rapidly and extensively albitizes graywacke at 350°C. 2. Experiments reacting basaltic glass with solutions ranging from seawater to fully saturated brines under a variety of conditions have failed to produce significant Na metasomatism such as observed in spilites.

254 . A) Gen. Cat.--Hydrothermal alteration

B) Toporkov, V. Y., 1983, Geochemical characteristics and mineralization criteria for metasomatites in some gold deposits: Geochemistry International, v. 20, no. 3, p. 162-174.

C) Purpose: define mineralization criteria in metasomatites

Methods: "spectral and chemical analyses"

Results: characteristic features of element migration are reflected in geochemical-activity series.

Quartz ore bodies (in order of decreasing activity):

W, Mo, Bi, Au, Cu, Ag, Be, S, As.

Quartz-sulfide bodies:

As, Au, Sn, Ag, S, W, Be, Zn, Cr, Cu.

Quartz-tourmaline-sulfide bodies:

S, Pb, Ag, Sn, Au, As, Bi, Sb, Zn, Cu.

Criteria for mineralization can be expressed by multiplicative indicator ratios; each type of deposit is best described by a different ratio.

255 . A) Gen. Cat.--Hydrothermal Alteration

B) Urabe, T.; and Scott, S. D., 1983, Geology and footwall alteration of the South Bay massive sulphide deposit: Canadian Journal of Earth Sciences, v. 20, no. 12, p. 1862-1879.

C) Purpose: to provide a detailed examination of the wall-rock alteration extending to 1250 m from the ore-bodies.

Methods: chemical analyses (XRF), electron microprobe.

Results: systematic variations in assemblages and compositions of hydrothermally produced minerals provide better lithochemical vectors to mineralization over a distance of a few hundred meters than do whole rock chemical analyses.

256 . A) Gen. Cat.--Alteration studies

B) Whitney, G., 1983, Hydrothermal reactivity of saponite: Clays and Clay Minerals, v. 31, no. 1, p. 1-8.

C) Purpose: investigate the nature and extent of the reactions of Fe-free saponite under experimental hydrothermal conditions.

Methods: XRD

Results: above 450°C, K-saponite dissolves and talc and phlogopite grow.

Fully ordered phlogopite-saponite or talc-saponite layers can be formed at 450°C, via intercrystalline layer transformations. No reactions were observed at temperatures less than 400°C. Na- and Ca-saponite react more slowly than K-saponite and do not produce mica.

257 . A) Gen. Cat.--Alteration studies

B) Yapp, C. S., 1983, Stable hydrogen isotopes in iron oxides - isotope effects associated with the dehydration of a natural goethite: *Geochimica et Cosmochimica Acta*, v. 47, no. 7, p. 1277-1287.

C) Purpose: study isotope trends in dehydration of goethite.

Methods: dehydration was accomplished in a quartz tube; analysis by mass spectrometry.

Results: closed system dehydration results in greater isotopic fractionation than open system dehydration, up to 250°C. This relationship apparently reverses at 300°C. Mineral D/H decreases with increasing dehydration in both systems. Data suggests that goethite can isotopically exchange with water during dehydration. Loss of H₂O and CO₂ is apparently diffusion controlled.

- 258 . A) Gen. Cat.--Alteration, potassic or Alteration, uranium deposits
- B) Cathelineau, M., 1984, Potassic alteration in French hydrothermal uranium deposits: *Mineralium Deposita*, v. 18, no. 1, p. 89-97.
- C) Purpose: to conduct a detailed study of the alteration products and authigenic minerals in some French hydrothermal uranium deposits.
- Methods: petrography, XRD, electron microprobe, fluid inclusions.
- Results: K-rich fluids appear to be favorable to uranium transportation and deposition. Therefore, correlative alteration, as phengite, adularia, or K-smectites alteration type, can be considered as guides in uranium prospecting.

259 . A) Gen. Cat.—Alteration

B) Mathieson, N. A., and Hodgson, C. J., 1984, Alteration, mineralization, and metamorphism in the area of the East South "C" ore zone, 24th level of the Dickenson mine, Red Lake, north western Ontario: Canadian Journal of Earth Sciences, v. 21, no. 1, p. 35-52.

C) Purpose: to map the geological relationships in the area of the ESC zone in the 24th level of the Dickinson mine, and to recognize and describe the various minerals and alteration types that occur in this area.

Methods: geologic mapping, petrography, chemical analyses.

Results: 1) hydrothermal alteration within the study area has been extensive. 2) at least four mineralogically and texturally different vein types have been identified in the study area. 3) The arsenopyrite-gold mineralization is interpreted to be replacement-type mineralization. 4) Alteration of the mafic metavolcanic rocks within the mine has had the effect of changing the bulk-rock composition such that subsequent metamorphism has produced a wide variety of mineral assemblages normally characteristic of pelitic schists. 5) The feldspar-destructive hydrothermal alteration of the mafic metavolcanic rocks is not associated with the gold mineralization types, although the two are broadly spatially related. 6) Gold mineralization was largely emplaced synchronously with early stages of the prograde, amphibolite facies metamorphism and attendant (presumably) intensive penetrative deformation of the area.

260 . A) Gen. Cat.--Sericite, hydrothermal

B) Parry, W. T.; Ballantyne, J. M.; Jacobs, D. C., 1984, Geochemistry of hydrothermal sericite from Roosevelt Hot Springs and the Tintic and Santa Rita porphyry copper systems: Economic Geology, v. 79, no. 1, p. 72-86.

C) Purpose: to present and discuss chemical compositions of hydrothermal sericite from the southwest Tintic, Utah, and Santa Rita, New Mexico, porphyry copper systems and from the Roosevelt Hot Springs, Utah, geothermal system.

Methods: petrography, electron microprobe.

Results: all sericite grains show some degree of chemical inhomogeneity.

Compositional variation of sericite within samples of cuttings from individual depth intervals from the geothermal well is much greater than variability in more intensely altered rocks from porphyry copper systems.

261 . A) Gen. Cat.--Hydrothermal alteration

B) Robert, F.; Brown, A. C., 1984, Progressive alteration associated with gold-quartz-tourmaline veins at the sigma mine, Abitibi Greenstone Belt, Quebec: Economic Geology, v. 79, no. 2, p. 393-399.

C) Purpose: To describe the alteration associated with the gold-quartz-tourmaline veins in this area.

Methods: petrography.

Results: Cryptic alteration provides clear evidence of early stage alteration (e.g., epidote to carbonate), whereas visible alteration, corresponding to a readily observed bleached zone adjacent to veins, indicates continued metasomatism marked especially by a more intense carbonitization of primary metamorphic minerals (e.g., biotite-chlorite to carbonate).

262 . A) Gen. Cat.—Hydrothermal alteration

B) Ustinov, V. I.; Aleksandrov, S. M.; Strichov, V. P.; Grinenko, V. A.,

1984, Isotope criteria for the origin of zoning in magnesian skarns:

Geochemistry International, v. 21, no. 4, p. 68-76.

C) Purpose: examine the origin and degree of participation of CO₂ during metasomatism.

Methods: mass spectrometry.

Results: $\delta^{13}\text{C}$ ranges from -9.6 to +0.5 ‰, while $\delta^{18}\text{O}$ ranges from +7.6 to +20.5 ‰ in these dolomite skarns. Plutonic CO₂ is established as being significant in the origin of zoning in skarns. The proportion of plutonic CO₂ decreases as the degree of metasomatism decreases.

263. A) Gen. Cat.--Hydrothermal alteration

B) Alt, J.C.; Honnorez, J., 1984, Alteration of the upper oceanic crust, DSDP site 417: mineralogy and chemistry: Contributions to Mineralogy and Petrology, v. 87, no. 2, p. 149-169.

C) Purpose: to determine chemical changes for most of the alteration stages identified in the basalts.

Methods: XRD, electron microprobe.

Results: alteration of basalts at Site 417 has proceeded through a series of stages at temperatures of up to about 50°C; circulation was controlled by the primary structure and permeability of the crust, and solution compositions varied with time due to reaction with basalts.

264 . A) Gen. Cat.--Hydrothermal alteration

B) Brown, W. P.; Kwak, T. A. P.; Askins, P. W., 1984, Geology and geochemistry of a F-Sn-W skarn system - The Hole 16 deposit, Mount Garnet, North Queensland, Australia: Australian Journal of Earth Sciences.

C) Purpose: suggest a genetic model for the Hole 16 deposit.

Methods: petrography, microprobe, SEM, fluid inclusion studies.

Results: Sn occurs near the contact of the granite in solid solution in garnet, and in cassiterite. Mass balance calculations indicate that 10 volumes of granite would have to be altered to endoskarn to produce the volume of skarn observed. The system was largely closed. FeCl_2 and CaF_2 were derived from greisenization processes; CaCl_2 and CO_2 were derived from skarn forming processes. Temperature was $\approx 600^\circ\text{C}$. Very little meteoric water was involved.

265 . A) Gen. Cat.--Alteration, postmagmatic

B) Ekwere, S. J., 1985, Li, F, and Rb contents and Ba/Rb and Rb/Sr ratios as indicators of postmagmatic alteration and mineralization in the granitic rocks of the Banke and Ririwai Younger Granite complexes, Northern Nigeria: Mineralium Deposita, v. 20, no. 2, p. 89-95.

C) Purpose: to demonstrate that Ba/Rb and Rb/Sr ratios as well as Li, F, and Rb concentrations can be used to indicate granitic rocks affected by postmagmatic alteration and mineralization within the Nigerian Younger Granite province.

Methods: chemical analyses (XRF, AA).

Results: the concentrations of Li, F, Rb, Sr, and Ba demonstrate that the granitic rocks of the Banke and Ririwai complexes belong to late phases of granite magmas rich in volatiles.

266. A) Gen. Cat.--Hydrothermal alteration

B) Hellingwerf, R. H.; and Baker, J. H., Wall-rock alteration and tungsten and molybdenum mineralizations associated with older granites in Western Bergslagen, Sweden: 1985, Economic Geology, v. 80, no. 2, p. 479-487.

C) Purpose: to report field and mineralogical relationships together with a reinterpretation of available geochemical and geophysical data on these mineralizations.

Methods: Petrography, chemical analyses, and geophysical methods.

Results: the tungsten and molybdenum occurrences in the Proterozoic supracrustal succession of the Hällefors-Härken-Nora area, western Bergslagen, Sweden, are genetically related to 1.9-1.8 b. y. older felsic magmatism.

267. A) Gen. Cat.--Alteration studies

B) Howard, J. J.; Roy, D. M., 1985, Development of layer charge and kinetics of experimental smectite alteration: Clay and Clay Minerals, v. 33, no. 2, p. 81-88.

C) Purpose: study smectite alteration rates.

Methods: XRD

Results: only 60% of the expandable layers remained after the smectite was hydrothermally reacted at 250°C for 180 days. The creation of a layer charge sufficient to cause collapse (i.e., the smectite to illite transformation) does not require K in solution; K must be introduced only when sufficient layer charge is present. Rate constants for the illitization reaction are between 1.0×10^{-3} and 2.3×10^{-3} /day with activation energies ≤ 3.5 kcal/mole. Dissolution is congruent at 180°C, but incongruent at 250°C.

268 . A) Gen. Cat.--Alteration

B) Shigley, J. E.; Brown, G. E., Jr., 1985, Occurrence and alteration of phosphate minerals at the Stewart Pegmatite, Pala District, San Diego County, California: *American Mineralogist*, v. 70, no. 3 and 4, p. 395-408.

C) Purpose: to better understand the occurrence and paragenesis of phosphate minerals in pegmatites.

Methods: electron microprobe, chemical analyses (emission spectrography)

Results: the Stewart pegmatite is an outstanding example of a complex lithium-rich granitic pegmatite which exhibits a vertical asymmetry in terms of many of its internal features. Lithiophilite and presumably amblygonite represent primary pegmatite minerals. Secondary alteration of lithiophilite involved oxidation, hydration, and cation leaching but little metasomatism.

269. A) Gen. Cat.--Alteration, hydrothermal, subseafloor
- B) Vivallo, W., 1985, Subseafloor hydrothermal alteration during the Early Proterozoic at Garpenberg, Central Sweden: *Mineralium Deposita*, v. 20, no. 1, p. 33-42.
- C) Purpose: to discuss the wall rock alteration in the Garpenberg deposit.
- Methods: chemical analyses, structural studies.
- Results: the Garpenberg deposit and its altered wall rocks were formed by hydrothermal activity. During alteration a general geochemical remobilization took place, with the exception of Ti, Zr, Y, and most of the REE which behaved as relatively immobile elements. Calcium and sodium were leached, whereas magnesium was enriched in the altered rocks.

HYDROTHERMAL DEPOSITS

1. A) Gen. Cat.--Hydrothermal deposits

B) Hawley, J. E., 1962, The Sudbury ores: their mineralogy and origin:

Canadian Mineralogist, v. 7, part 1, p. 1-202.

C) Purpose: to examine the mineralogy and origin of the Sudbury ores.

Methods: chemical, petrological, mineralogical.

Results: among other mechanisms, hydrothermal "secondary" ore genesis is discussed.

2 . A) Gen. Cat.--Hydrothermal deposits

B) Williams, S. A., 1963, Complex silver ores from Morey, Nevada: Canadian Mineralogist, v. 7, p. 478-484.

C) Purpose: to analyze the silver ores from Morey, Nevada.

Methods: collected minerals were studied goniometrically.

Results: the silver ores are said to occur as kryptothermal fracture fillings cutting a nevadite intrusive. Minerals in the ores are described.

3 . A) Gen. Cat.--Hydrothermal deposits

B) Petruk, W., 1971, Depositional history of the ore minerals: Canadian Mineralogist, v. 11, p. 396-401.

C) Purpose: this is part of a study done on the silver-arsenide deposits of the Cobalt-Gowganda Region, Ontario.

Methods: data reported in an earlier paper in this study is used to make interpretations of the ore deposits as regards genesis.

Results: discussion of characteristics of the ore minerals is made to show their bearing on the ore deposition. It is speculated that hydrothermal fluids, heated and otherwise affected by an intruding diabase sill deposited the ores.

4. A) Gen. Cat.--Hydrothermal deposits

B) Birnie, R. W.; Hall, J. H., 1974, The geochemistry of El Misti Volcano, Peru fumaroles: Bulletin Volcanologique, v. 38, no. 1, p. 1-15.

C) Purpose: to examine fumarole deposits from El Misti volcano.

Methods: temperatures at fumarole vents were estimated, analysis of samples was done chemically (atomic absorption)

Results: The mineralogy of the fumaroles is sulfur, anhydrite, gypsum and ralstonite which precipitated by acid vapors at 100^o C to 125^o C.

There are 2 to 6 parts per thousand chloride concentrations and several ppm sodium, potassium, magnesium calcium, iron and zinc concentrations in the vapor. Near complete leaching of the wall rocks is indicated. Other geochemistry is described and a marine contaminated heavy water source at depth is indicated as the parent water for the vapors.

5. A) Gen. Cat.--Hydrothermal Uranium deposits

B) Fehn, U.; Cathles, L. M.; Holland, H. D., 1978, Hydrothermal convection and uranium deposits in abnormally radioactive plutons: *Economic Geology*, v. 73, no. 8, p. 1556-1566.

C) Purpose: to investigate whether radioactive decay can generate hydrothermal flow regimes of sufficient magnitude to transport the quantities of uranium found in hydrothermal uranium deposits associated with abnormally radioactive plutons.

Methods: thermodynamic analyses

Results: hydrothermal uranium deposits commonly found associated with radioactive granites can be produced by convection driven by radioactive heat generated in the intrusive mass.

6 . A) Gen. Cat.--Hydrothermal ore formation

B) Drever, J.; Lawrence, J. R.; Artiveiler, R. C., 1979 , Gypsum and halite from the Mid-Atlantic Ridge, DSDP site 395: Earth and Planetary Science Letters, v. 42, p. 98-102.

C) Purpose: to find a mechanism for the formation of gypsum and halite in samples taken from DSDP site 395.

Methods: mineralogy was confirmed by x-ray diffraction and semi-quantitative x-ray energy spectrometry.

Results: gypsum and halite crystals were found together with saponite and phillipsite, $\delta^{34}\text{S}$ value for the gypsum indicates a seawater source for the sulfate. The $\delta^{18}\text{O}$ values for the saponite and phillipsite indicate either formation from normal seawater at about 55°C or formation from ^{18}O -depleted seawater at lower temperature .

The gypsum (which may follow anhydrite) was formed by reaction of Ca^{2+} from basalt and SO_4^{2-} from seawater. The halite may have been formed when water was consumed by hydration of basalt.

More probably, the gypsum was precipitated as anhydrite at temperature greater than 60°C . As temperature dropped, the anhydrite converted to gypsum. The conversion would consume water, cause precipitation of halite and plug the vein, preventing dissolution of the halite.

7 . A) Gen. Cat.--Hydrothermal ores

B) Lang, B., 1979, The base metals-gold hydrothermal ore deposits of Baia Mare, Romania: Economic Geology, v. 74, no. 6, p. 1336-1351.

C) Purpose: to summarize the general data and correlate the tectonic conditions governing the development of the volcanic activity and the structural control of the ore.

Methods: chemical analyses, field mapping, fluid inclusions, petrography.

Results: the significant aspects of the hydrothermal activity are metamorphism of the country rock and metallogenesis. There is a direct relationship between the two forms both in terms of time continuity and genesis.

8 . A) Gen. Cat.--Hydrothermal deposits

B) Nairn, I. A.; Wiradiradjn, S., 1980, Late Quaternary hydrothermal explosion breccias at Kawerau Geothermal Field, New Zealand: Bulletin Volcanologique, v. 43, no. 1, p. 1-14.

C) Purpose: to examine the remnants of hydrothermal explosions in New Zealand.

Methods: petrography, chemical (C-14 dating)

Results: hydrothermally altered tuff, ignimbrite and rhyolite in a silty hydrothermal clay matrix is described and analyzed.

9 . A) Gen. Cat.--hydrothermal deposits

B) Stakes, D. S.; O'Neil, J. R., 1982, Mineralogy and stable isotope geochemistry of hydrothermally altered oceanic rocks: Earth and Planetary Science Letters, v. 57, p. 285-304.

C) Purpose: to examine the mineralogy and stable isotope geochemistry of hydrothermally altered oceanic rocks.

Methods: samples collected at the East Pacific Rise and Mid-Atlantic Ridge were analyzed by petrography, x-ray diffraction, microprobe and other chemical means.

Results: information about temperatures of alteration and seawater/rock ratios for various hydrothermal regimes within the oceanic crust was gained.

HYDROTHERMAL FLUIDS

1. A) Gen. Cat.--Gaseous fluids

B) Walker, A. L.; Buchanan, A. S., 1969, Geochemical processes in ore formation, Part II: Kinetics of high temperature gas phase metal transport and the relation of the model systems to the natural environment: Economic Geology, v. 64, no. 8, p. 923-931.

C) Purpose: to establish whether vapor phase transport processes could be effective in bringing about segregation and recrystallization of the economically important base metal sulfides of Pb, Zn, and Cu.

Methods: experimental petrology, thermodynamic analyses.

Results: preliminary studies have been carried out on the rate of reaction of gaseous HCl with galena at temperatures ranging from 125° to 532°C. In the restricted temperature range 498-532°C the reaction is of order 0.8 with respect to HCl and has a very small or zero value of activation energy. It is concluded that the reaction is predominantly heterogeneous in this region and that the rate determining step may be adsorption of HCl by the solid. At lower temperatures, the heterogeneous reaction becomes complicated by retention of the relatively involatile product $PbCl_2$ by the surface. At significantly higher temperatures the reaction may become predominantly homogeneous.

Rate studies on the conversion of sphalerite to $ZnCl_2$ by the gaseous HCl indicate a zero order reaction (in respect to HCl) when HCl is present in large excess and temperatures in the range 550-620°C are used. The activation energy for the reaction was found to be 35.8 kcal per mole of ZnS converted. Comparison with the rate of attack of HCl on PbS and Cu_2S gave an order of $PbS \succ ZnS \succ Cu_2S$.

2. A) Gen. Cat.--Hydrothermal fluids

B) Walker, A. L.; Buchanan, A. S., 1969, Geochemical processes in ore formation, Part I: The production of hydrothermal fluids from sedimentary sequences: Economic Geology, v. 64, no. 8, p. 919-922.

C) Purpose: to investigate the effects of heating a number of rock samples at low pressures.

Methods: mass spectrometry.

Results: many sedimentary rock types appear to contain concentrations of base metals; however, black shales containing carbonaceous material appear to be of particular importance in this respect. On heating such a rock, a highly reactive and complex gas mixture is produced which has considerable mineralizing powers and in suitable circumstances may result in producing high local concentration of recrystallized minerals. The temperatures required for these processes are geologically reasonable (of the order of 500 - 700°C).

3. A) Gen. Cat.--hydrothermal fluids

B) Helgeson, H. C., 1970, Reaction rates in hydrothermal flow systems:

Economic Geology, v. 65, no. 3, p. 299-303.

C) Purpose: to determine approximate limiting flow characteristics for long distance travel of acid hydrothermal vein solutions through reactive granitic rocks.

Methods: thermodynamic analyses.

Results: provided the volumes, widths, and geometry of the veins and associated alteration zones are known in ore deposits such as Butte, rate equations like those derived above can be used in conjunction with thermodynamic data, mass transfer calculations, fluid inclusion analyses, and field observations to predict the spatial occurrence of ore, and to characterize the chemical environment in fracture systems as a function of time during rock alteration and ore deposition.

- 4 . A) Gen. Cat.--Natural waters, hydrothermal effects and gold
- B) Weissberg, B. C., 1970, Solubility of gold in hydrothermal alkaline sulfide solutions: Economic Geology, v. 65, no. 5, p. 551-556.
- C) Purpose: to present new experimental data on the solubility of gold in strongly alkaline and near neutral sulfide solutions between 150 and 290°C.

Methods: chemical analyses.

Results: the solubility of gold experimentally determined at elevated temperatures in alkaline Na_2S solutions ranges from 1 to 6 ppm Au in solutions containing from .25 to .9 moles $\text{Na}_2\text{S}/\text{kg}$ solution at temperatures between 150 and 290°C. In less alkaline solutions, where HS-ion predominates, the experimentally determined solubility of gold ranges from 100 to 200 ppm Au in solutions containing from .2 to .3 moles NaHS/kg solution at temperatures between 150 and 250°C, in good agreement with earlier workers.

5. A) Gen. Cat.--Natural waters, gold content; Natural waters, hydrothermal effects

B) Gosling, A. W.; Jenne, E. A.; Chao, T. T., 1971, Gold content of natural waters in Colorado: Economic Geology, v. 66, no. 2, p. 309-313.

C) Purpose: to evaluate the potential for direct hydrogeochemical prospecting for gold.

Methods: chemical analyses (neutron activation)

Results: the average gold content of waters from mines or gold-enriched igneous and metamorphic terrane is not noticeably higher than the gold content of waters draining gold-barren terrane.

6 . A) Gen. Cat.--Hydrothermal fluids, Cu-bearing

B) White, W. S., 1971, A paleohydrologic model for mineralization of the White Pine copper deposit, Northern Michigan: Economic Geology, v. 66, no. 1, p. 1-13.

C) Purpose: to make a quantitative evaluation of various paleohydrologic models for the origin of the White Pine copper deposit.

Methods: hydronamic analyses

Results: the models involve lateral migration of fluids through the subjacent Copper Harbor conglomerate to the site of the deposit and stripping of copper from these solutions where they percolated upward through the Nonesuch Shale. Ground water entering the Nonesuch Shale up dip from White Pine is not a possible source of mineralizing solutions.

7. A) Gen. Cat.--Hydrothermal fluids; element distribution

B) Radtke, A. S.; Heropoulos, C.; Fabbi, B. P.; Scheiner, B. J.; Essington, M., 1972, Data on major and minor elements in host rocks and ores, Carlin gold deposit, Nevada: Economic Geology, v. 67, no. 7, p. 975-978.

C) Purpose: to summarize and make available a large amount of data on the content of major and minor elements in the host rocks and ores of the Carlin gold deposit and to show the changes in the abundance of these elements as a result of hydrothermal mineralization and subsequent oxidation.

Methods: chemical analyses (AA, XRF, rapid rock analyses, semiquantitative spectrographic analyses, colorimetric analyses, instrumental mercury meter analyses, Leco combustion system analyses).

Results: as a result of the removal of carbonate during postore oxidation, the shallow oxidized ores underwent residual enrichment in such elements as silicon, aluminum, potassium, sodium, phosphorous, barium, titanium, and zirconium. Although the average content of gold remained about the same, the average abundance of most of the other elements introduced during mineralization decreased after oxidation.

- 8 . A) Gen. Cat.--Mineral zoning, hydrothermal fluids
- B) Large, R. R., 1975, Zonation of hydrothermal minerals at the Juno Mine, Tennant Creek Goldfield, Central Australia: Economic Geology, v. 70, no. 8, p. 1387-1413.
- C) Purpose: to demonstrate that the structural, mineralogical, and chemical features of the zonation within the Juno Lode indicate that the deposit has a subsurface hydrothermal replacement origin.
- Methods: petrography, chemical analyses, sulfur isotopes, thermodynamic analyses.
- Results: A primary magmatic source for the sulfur appears unlikely as the trend of isotopic fractionation indicates that $\delta^{34}\text{S}$ in the solution was near +20 per mil. Formation waters ("evolved sea water" and interlayer water) released from argillaceous sediment in the vicinity of granitic and rhyolite porphyry intrusions subsequent to a period of active felsic volcanism provide the most probable source for the hydrothermal solutions.

9 . A) Gen. Cat.—Fluids, hydrothermal

B) McCarthy, J. S.; Jacobsen, J. B. E., 1976, The mineralizing fluids of the Artonvilla Copper Deposit: An example of a silica-deficient, alkaline, hydrothermal system: *Economic Geology*, v. 71, no. 1, p. 131-138.

C) Purpose: to describe the composition and reaction of the ore fluid.

Methods: chemical analyses, petrography.

Results: most of the metals were transported as anionic oxycomplexes in alkaline fluid. These fluids reacted with the country rocks, evolving continuously in consequence, leading ultimately to the formation of a sericitic halo at the outer extremity of the ore body. Subsequent retrograde reaction resulted in zonation of ore and gangue mineral assemblages.

10. A) Gen. Cat.--fluids, hydrothermal

B) Villas, R. N.; Norton, D., 1977, Irreversible mass transfer between circulating hydrothermal fluids and the Mayflower Stock: Economic Geology, v. 72, no. 8, p. 1471-1504.

C) Purpose: to present results of preliminary studies whose objectives were to develop and test methods useful in quantifying parameters dealing with mineral deposition in pluton environments.

Methods: chemical analyses, thermodynamic analyses, porosity studies, electron microprobe.

Results: The igneous event that produced the Mayflower Stock resulted in the development of abundant continuous fractures within the stock as it cooled below solidus temperatures. This fracturing generated permeabilities in the darcy range and allowed relatively large masses of fluids to circulate in and out of the stock. This convective transfer of heat cooled the entire stock to 0.3 of the initial thermal anomaly in 1.8×10^5 years, which is approximately 1.5 times faster than if the rock were impermeable and cooled by pure conduction.

11. A) Gen. Cat.--Fluids, hydrothermal

B) Bellanca, A.; Censi, P.; DiSalvo, P.; Neri, R., 1984, Textural, chemical, and isotopic variations induced by hydrothermal fluids on Mesozoic limestones in northwestern Sicily: *Mineralium Deposita*, v. 20, no. 1, p. 78-85.

C) Purpose: to present results of textural and compositional investigations carried out on carbonate materials where fluorite, barite, and calcite mineralizations of hydrothermal origin occur.

Methods: petrography, chemical analyses (AA), XRD, isotope studies.

Results: the geochemical behavior of the minor elements indicate variations in chemical composition (increase of Mn, Fe, and Sr and removal of Mg) as a result of interactions between mineralizing fluids and host rocks.

Textural features indicate variations in the degree of calcite recrystallization and silicification that appear to be more marked in rocks that show more evident effects of mineralization.

1 . A) Gen. Cat.--Geothermal systems

B) Ivanov, V. V., 1959, Present-day hydrothermal activity within the Kurile-Kamchatka Island arc and its relation to volcanicity: Bulletin Volcanologique, v. 20, p. 137-154.

C) Purpose: to describe the hydrothermal system of Kamchatka-Kurile region.

Methods: chemical analysis of waters and gases of the geothermal system.

Results: types of water and gases are discussed on chemical and physical bases. Metal deposits precipitated from thermal waters are discussed.

2 . A) Gen. Cat.--Geothermal systems

B) Naboko, S. I., 1959, Volcanic exhalations and products of their reactions as exemplified by Kamchatka-Kuriles volcanoes: Bulletin Volcanologique, v. 20, 121-136.

C) Purpose: analysis of volcanic exhalations and their reactions of the Kamchatka-Kuriles areas.

Methods: chemical analysis.

Results: volcanic exhalations and their reactions are discussed in detail.

3 . A) Gen. Cat.--Geothermal systems

B) Averiev, V. V.; Ivanov, V. V.; Piip, B. I., 1960, Problems of using volcanic thermal of the Kurile-Kamchatka Island arc for power: Bulletin Volcanologique, v. 23, p. 257-265.

C) Purpose: to explore problems with using hydrothermal for power.

Methods: use of data accumulated by previous workers to form opinions on the use of thermal for power.

Results: a chart of the principle genetic types of thermal waters in the Kurile-Kamchatka including formation conditions and chemical components is given.

4 . A) Gen. Cat.—Hydrothermal systems or Alteration studies

B) Lovering, T. S.; Shepard, A. O., 1960, Hydrothermal alteration zones caused by halogen acid solutions, East Tintic district, Utah: American Journal of Science, v. 258-A, p. 215-229.

C) Purpose: examine alteration of latite and limestone by hydrothermal fluids.

Methods: XRD, petrography, SEM, field mapping

Results: mineral zones parallel the latite-limestone contact. The latite has been argillized to montmorillonite and minor kaolinite in a zone 4 ft. wide. The limestone has been replaced by quartz and hematite, in a zone 5-8ft. wide, and, locally, contains a magnaniferous zone. Kaolinite, diaspore, and fluorite appear further from the contact. Data indicate alteration by acid fluids containing halides of Fe, Al, and Si at temperatures up to 300°C. Zonation is due to increasing pH as fluids react with wall rock. Si/Al ratio controls the formation of kaolinite or montmorillonite.

5 . A) Gen. Cat.--Geothermal systems

B) Sviatlovsky, A. E., 1960, Thermal underground waters of the Kamchatka and the role of recent tectonics and volcanism in their dynamics: Bulletin Volcanologique, v. 23, p. 265-271.

C) Purpose: to relate the hydrothermal systems at Kamchatka to tectonics and volcanism in the area.

Methods: descriptions of structure and hydrology.

Results: changes in structure due to tectonics and volcanism are related to changes in the hydrothermal dynamics.

6 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Hulston, J. R.; McCabe, W. J., 1962, Mass spectrometer measurements in the thermal areas of New Zealand. Part 1. Carbon dioxide and residual gas analyses: *Geochimica et Cosmochimica Acta*, v. 26, no. 3, p. 383-397.

C) Purpose: obtain information on the processes that control discharge composition.

Methods: mass spectrometry.

Results: argon is of atmospheric origin. Data indicates argon loss underground, and an unidentified source of N_2 . Temperatures calculated using CO_2 and CH_4 data are in reasonable agreement with measured values.

7 . A) Gen. Cat.-- Active and semidormant hydrothermal systems.

B) Hulston, J. R.; McCabe, W. J., 1962, Mass spectrometer measurements in the thermal areas of New Zealand. Part 2. Carbon isotopic ratios: *Geochimica et Cosmochimica Acta*, v. 26, no. 3, p. 399-410.

C) Purpose: ascertain use of C isotopy in $\text{CO}_2\text{-CH}_4$ geothermometry.

Methods: mass spectrometry.

Results: in general, $\delta^{13}\text{C}$ ranges from 0 to $-7^\circ/\text{oo}$, relative to PDB.

Calculations using isotopic equilibrium between CO_2 and CH_4 give temperatures that are in good agreement with bore hole measurements.

8 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Ellis, A. J.; Mahon, W. A. J., 1964, Natural hydrothermal systems and experimental hot water/rock interactions: *Geochimica et Cosmochimica Acta*, v. 28, no. 8, p. 1323-1357.

C) Purpose: compare natural vs. experimental hydrothermal reactions.

Methods: emission flame photometry, atomic absorption flame photometry, wet chemical techniques, petrography.

Results: experimental rock/water interaction at 150-350°C indicates that Cl, B, As, F, and NH₃ are liberated into solution easily. Rock/water interaction can account for observed chemistry of thermal waters, without invoking a magmatic component. Composition of hydrothermal water that has reacted with greywacke is very similar to that of water reacted with volcanic rock.

9 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Mazor, E.; Wasserburg, G. J., 1965, Helium, neon, argon, krypton and xenon in gas emanations from Yellowstone and Lassen volcanic National Parks: *Geochimica et Cosmochimica Acta*, v. 29, no. 5, p. 443-454.

C) Purpose: establish composition of gases associated with thermal waters and determine if they contain a juvenile component.

Methods: mass spectrometry.

Results: isotopic composition of the 4 heavier gases indicate an atmospheric origin for these gases. Excess He is attributed to radioactive decay of wall rock or possibly from deep mixing.

10 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Gunter, B. D.; and Musgrave, B. C., 1966, Gas chromatographic measurements of hydrothermal emanations at Yellowstone National Park: *Geochimica et Cosmochimica Acta*, v. 30, no. 11, p. 1175-1189.

C) Purpose: locate features promising for isotopic analyses.

Methods: gas chromatography.

Results: source of methane could not be ascertained. There is a correlation between argon and nitrogen and other gas phases. This is interpreted to indicate an atmospheric origin for these gases.

11 . A) Gen. Cat.--Geothermal systems

B) Hayakawa, M., 1966, Geophysical study of Matsukawa geothermal area, Iwake Prefecture, Japan: Bulletin Volcanologique, v. 29, p. 499-516.

C) Purpose: to describe the study of the Matsukawa geothermal area and the area itself.

Methods: petrographic analysis of cores from boreholes and seismic studies.

Results: borehole cores and seismic data are discussed.

12 . A) Gen. Cat.--Active and semidormant hydrothermal systems or Alteration studies.

B) Miller, A. R.; Densmore, C. D.; Degens, E. T.; Hathaway, J. C.; Manheim, F. T.; McFarlin, P. F.; Pocklington, R.; Jokela, A., 1966, Hot brines and recent iron deposits in deeps of the Red Sea: *Geochimica et Cosmochimica Acta*, v. 30, no. 3, p. 341-359.

C) Purpose: examine an active, depositing hydrothermal system.

Methods: wet chemical techniques, AAS, use of published data, XRD, petrography.

Results: interaction of hot, weakly acidic brines, with high metal concentrations, with oxidizing, alkaline Red Sea water promotes deposition of metal oxides and sulfides. Geologic, chemical, and oxygen isotope data indicate a deep, unidentifiable source for thermal waters.

13 . A) Gen. Cat.--Geothermal systems

B) Averiev, V. V., 1967, Hydrothermal process in volcanic areas and its relations to magmatic activity: Bulletin Volcanologique, v. 30, p. 51-62.

C) Purpose: to relate hydrothermal dynamics to volcanic processes.

Méthods: generally thermodynamic analysis of sytems.

Results: features of hydrothermal processes is discussed in detail including temperatures and heat capacities of such systems, as is length of time of existence of hydrothermal systems. These characteristics are related to volcanic processes and intrusive body processes.

14. A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Ellis, A. J.; Mahon, W. A. J., 1967, Natural hydrothermal systems and experimental hot water/rock interactions (Part II): *Geochimica et Cosmochimica Acta*, v. 31, no. 4, p. 519-538.

C) Purpose: investigate reaction of rocks with water at T's of 400 - 600°C and P's of 1000-1500 bars.

Methods: petrography, wet chemical analyses.

Results: most solutes (ions, SiO₂, NH₃) are controlled in concentration by solubility or ion exchange equilibria. Na/K (in solution) ranges from 10-15 at 250°C to 4 at 600°C. Mg is present in very low concentration only. Cs, Cl, and B are effectively leached from wall rock.

15. A) Gen. Cat.--Geothermal areas

B) Polak, B. G., 1967, An energy appraisal of volcanic and hydrothermal phenomena (on the example of Kamchatka): Bulletin Volcanologique, v. 30, p. 129-138.

C) Purpose: to analyze energy production of volcanic and hydrothermal processes.

Methods: various geophysical data were collected in Kamchatka and analyzed.

Results: conductive heat flow, volcanic activity and heat of discharge by hydrothermal are described and compared.

16 . A) Gen.Cat.--Hydrothermal systems

B) Helgeson, H.C., 1968, Geologic and thermodynamic characteristics of the Salton Sea geothermal system: American Journal of Science, v. 266, no. 3, p. 129-166.

C) Purpose: discuss the subsurface distribution of T, P, enthalpy and salinity at Salton Sea.

Methods: calculations based on published data.

Results: underground temperatures range from 300°C at 3000 ft. to 360° at 7000 ft. No steam exists below the surface, rather, all steam is the product of flashing of the liquid phase. Alteration has produced albite-epidote facies at 4000 ft. Temperature depth profiles below 3000 ft. approach adiabatic gradients, as the reservoir is insulated by shale above. Thermal convection of pore fluids is the primary mechanism of heat transfer. Salinities increase to 3000 ft. and then may be constant.

17. A) Gen. Cat.--Geothermal systems

- B) Keith, T. E. C.; Muffler, L. J. P.; Cremer, M., 1968, Hydrothermal epidote formed in the Salton Sea geothermal system, California: American Mineralogist, v. 53, no. 9 and 10, p. 1635-1644.

- C) Purpose: to record significant data obtained from the study of two epidotes from the Salton Sea geothermal system, and to present evidence that these epidotes are products of the hydrothermal metamorphism presently taking place.

Methods: petrography, chemical analyses (wet chemistry), XRD.

Results: both epidotes formed at temperatures of approximately 320°C and under 125-145 atm. hydrostatic pressure. Variation in oxygen fugacity is the mechanism most likely to account for the different epidote compositions and mineral associations.

- 18 . A) Gen. Cat.--Active and semidormant hydrothermal systems.
- B) Raymahashay, B. C., 1968, A geochemical study of rock alteration by hot springs in the Paint Pot Hill area, Yellowstone Park: *Geochimica et Cosmochimica Acta*, v. 32, no. 5, p. 499-522.
- C) Purpose: describe hot springs and patterns of rock alteration associated with them.
- Methods: XRD, wet chemical techniques, petrography.
- Results: acid springs result in formation of the secondary assemblage kaolinite-alunite-silica minerals. Alkaline springs are lined with silica deposits that obscure alteration of the wall rocks. Chemistry of water, however, is compatible with a Na-montmorillonite phase. Wall rock is rhyolite in all cases.

19. A) Gen.Cat.--Hydrothermal systems

B) Helgeson, H.C., 1969, Thermodynamics of hydrothermal systems at elevated temperatures and pressures: American Journal of Science, v. 267, no. 7, p. 729-804.

C) Purpose: summarize methods and data on properties and analysis of hydrothermal systems.

Methods: calculations based on published data.

Results: sufficient data is available for calculation of equilibrium constants, in hydrothermal solution, for many reactions; when data is incomplete, entropy and heat capacity estimates may be utilized. Tables are included that give ΔH° , S° , and heat capacity power function coefficients for various phases of interest, and ΔH°_R , ΔS°_R and $\log K$ for various reactions of interest in hydrothermal systems.

20 . A) Gen. Cat.--Geothermal systems

B) Marinelli, G., 1969, Some geological data on the geothermal areas of
Tuscany: Bulletin Volcanologique, v. 33, p. 319-333.

C) Purpose: to describe several features of the Tuscany geothermal area and
state some conclusions based on the observations.

Methods: petrography, mineralogy and structure is described and conclusions
are drawn from them.

Results: phreatic explosion craters are described, tectonic features are
explained and secondary mineralization is described and from those minerals
it is inferred that no steam is present in the hydrothermal aquifer .

21. A) Gen. Cat.--Geothermal systems, mineral deposition, metastibnite.
- B) Brookins, D. G., 1970, Metastibnite from the Geysers Sonoma County, California: American Mineralogist, v. 55, no. 11 and 12, p. 2103-2104.
- C) Purpose: to describe an occurrence of metastibnite at the Geysers.
Methods: XRD, emission spectrography, sulfur isotopes.
Results: the author concludes that the red material described is indeed metastibnite, and that The Geysers is the second location in the United States where this rare mineral is found, the other being Steamboat Springs, Nevada, where both metastibnite and stibnite occur in association with Hg and As minerals.

22. A) Gen. Cat.--Hydrothermal systems.

B) Browne, P.R.L.; Ellis, A.J., 1970, The Ohaki-Broadlands hydrothermal area, New Zealand: mineralogy and related geochemistry: American Journal of Science, v. 269, no. 2, p. 97-131.

C) Purpose: describe hydrothermal alteration, and correlate mineral stabilities with temperatures and compositions of fluids in deep drill holes.

Methods: petrography, differential thermal analysis, quantitative infra-red spectroscopy, XRD, flame photometry. Method of fluid analysis not discussed.

Results: deep waters are dilute chloride-bicarbonate solutions with appreciable CO_2 ($m_{\text{CO}_2} = 0.15$). Alteration yields an equilibrium assemblage of mica, k-spar, albite, chlorite, calcite, and quartz. Metallic sulfides occur at depth in some wells. Changes in alteration mineralogy are due to boiling off of waters and/or changes in pH.

23 . A) Gen. Cat.--Geothermal systems, active

B) White, D. E.; Muffler, L. J. P.; Truesdell, A. H., 1971, Vapor-dominated hydrothermal systems compared with hot-water systems: Economic Geology, v. 66, no. 1, p. 75-97.

C) Purpose: to summarize the characteristics of both systems, and discuss the implications of these characteristics.

Methods: chemical analyses, temperature and pressure measurements.

Results: fundamental differences do exist between the two main types of natural hydrothermal systems, and each type is recognizable by geologic, physical, and geochemical criteria. In addition, the authors believe that steam and water must coexist in the reservoirs of these systems that yield dry steam at the surface.

24 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Ellis, A. J.; McFadden, I. M., 1972, Partial molal volumes of ions in hydrothermal solutions: *Geochimica et Cosmochimica Acta*, v. 36, no. 4, p. 413-426.

C) Purpose: give data on partial molar volumes of NaHCO_3 and NaHS in water at up to 200°C .

Methods: wet chemical techniques.

Results: partial molal volumes of both solutions increase slightly with increasing T, up to a maxima at 75°C , and then decrease rapidly with increasing T. The data can be used to calculate the effects of pressure on equilibria involving ions, and compares favorably with experimental solubilities.

25 . A) Gen. Cat.—Hydrothermal systems

B) Mahon, W.A.J.; Finlayson, J.B., 1972, The chemistry of the Broadlands geothermal area, New Zealand: American Journal of Science, v. 272, no. 1, p. 48-68.

C) Purpose: correlate chemistry of geothermal waters with geology and conditions at depth.

Methods: not discussed.

Results: at depth, waters are saturated with quartz and near saturation with calcite. Heavy metal concentrations are low, but precipitates contain high concentrations of heavy metals and As. D/H ratios indicate a meteoric source for waters. Gas content is high; CO₂ is approximately 0.14 molal. Broadlands contains less metals and more gas in its fluids than the Wairakei field; concentrations of these constituents at Broadlands are similar to those at Kaweru and Waiotapu.

- 26 . A) Gen. Cat.--Active and semidormant hydrothermal systems
- B) Mazor, E., 1972, Paleotemperatures and other hydrological parameters deduced from noble gases dissolved in groundwaters; Jordan Rift Valley, Israel: *Geochimica et Cosmochimica Acta*, v. 36, no. 12, p. 1321-1336.
- C) Purpose: study the usefulness of the rare gas - paleotemperature method.
Methods: mass spectrometry.
Results: isotopic abundances of Ne, Ar, Kr, and Xe are atmospheric and concentrations indicate equilibration with water at 15-22°C. This shows that the waters are meteoric in origin, and do indicate paleotemperatures (up to 30,000 years BP, in this case) even though they may have been heated up to 63°C. Excess radiogenic He may indicate a source with an Ra excess.

27 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Poty, B.; Holland, H. D.; Borcsik, M., 1972, Solution - mineral equilibria in the $MgO - SiO_2 - H_2O - MgCl_2$ at $500^{\circ}C$ and 1 kbar: *Geochimica et Cosmochimica Acta*, v. 36, no. 10, p. 1101-1113.

C) Purpose: supply thermodynamic data for this system and study equilibria in hydrothermal systems.

Methods: AAS, XRD.

Results: quench pH's of $MgCl_2$ solutions depend on the phases the solution is in equilibrium with. Quench pH is controlled by reactions with HCl and precipitation of Mg oxides or chlorides during cooling. Solutions equilibrated with quartz + talc have low quench pH's, while those equilibrated with forsterite + talc or forsterite + brucite have neutral to high quench pH's, explaining the lack of proton metasomatism around ultramafic intrusives.

28 . A) Gen. Cat.--Geothermal systems, active

B) Walter, M. R., 1972, A hot spring analog for the depositional environment of precambrian iron formations of the Lake Superior Region: Economic Geology, v. 67, no. 7, p. 965-980.

C) Purpose: to provide additional data on models for iron formation depositional environment.

Methods: field studies, literature review.

Results: the stromatolites of the Gunflint and Biwabik formations grew subaqueously in turbulent water of pH greater than 6 containing more than 115 ppm silica.

29. A) Gen. Cat.--Geothermal systems, active

B) Bargar, K. E.; Beeson, M. G.; Fournier, R. O.; Muffler, L. J. P.,
1973, Present-day deposition of lepidolite from thermal waters
in Yellowstone National Park: *American Mineralogist*, v. 58,
no. 9 and 10, p. 901-904.

C) Purpose: to report on lepidolite deposited from a modern geothermal
system.

Methods: drill hole studies, temperature measurements, XRD, petrography,
electron microprobe, chemical analyses.

Results: the lepidolite appears to be precipitating at 130° to 140°C
from water of the presently active geothermal system . This water
has a very high fluorine content and an extraordinarily high ratio
of lithium and potassium.

30 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Baskov, Y. A.; Vetshteyn, V. Y.; Surikov, S. N.; Tolstikhin, I. N.; Malyuk, G. A.; Mishina, T. A., 1973, Isotope composition of H, O, C, Ar, and He in hot springs and gases in the Kuril-Kamchatka volcanic region as indicators of formation conditions: *Geochemistry International*, v. 10, no. 2, p. 130-138.

C) Purpose: use isotope data to determine the origin of thermal waters in the Kuril-Kamchatka area.

Methods: mass spectrometry.

Results: isotopic composition of H, O, and Ar indicate that most of these thermal waters are atmospheric or marine in origin. Anomalously high ^3He concentrations suggest that this gas may be of mantle origin. Organic matter in sediments may contribute to low $\delta^{13}\text{C}$ (to -3.2).

31 . A) Gen. Cat.--Hydrothermal systems

B) Eslinger, E.V.; Savin, S.M., 1973, Mineralogy and oxygen isotope geochemistry of the hydrothermally altered rocks of the Ohaki-Broadlands, New Zealand, geothermal area: *American Journal of Science*, v. 273, no. 3, p. 240-267.

C) Purpose: investigate altered rocks in Broadland geothermal area.

Methods: mass spectrometry, XRD.

Results: isotopic equilibrium between coexisting silicate phases was attained if clay mineralogy was simple and in chemical equilibrium with the surroundings. A quartz-illite geothermometer was calculated empirically for $160^{\circ} < T < 270^{\circ}\text{C}$, and is given by:

$$1000 \ln \alpha_{\text{quartz-illite}} = 0.95 (10^6 T^{-2}) + 0.88.$$

The thermal water is meteoric in origin and is enriched in O^{18} due to rock-water interactions.

32 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Fournier, R. O.; Truesdell, A. H., 1973, An empirical Na-K-Ca geothermometer for natural waters: *Geochimica et Cosmochimica Acta*, v. 37, no. 5, p. 1255-1275.

C) Purpose: develop a way to estimate the last temperature of water-rock interaction.

Methods: calculations based on published data.

Results: data for most geothermal water cluster near a straight line when plotted as the function $\log(\text{Na}/\text{K}) + \beta \log(\text{Ca}^{1/2}/\text{Na})$ vs. reciprocal of temperature, where $\beta = 1/3$ if water equilibrated below 100°C , and $4/3$ if over 100°C . Continued water - rock reactions may occur as water cools adiabatically, dissolving Ca and giving T's that are too low. Extra Na or K in the water would result in T's that are too high.

33 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Gunter, B. D., 1973, Aqueous phase-gaseous phase material balance studies of argon and nitrogen in hydrothermal features at Yellowstone National Park: *Geochimica et Cosmochimica Acta*, v. 37, no. 3, p. 495-513.

C) Purpose: clarify the relationship between hydrothermal fluids and magmatic fluids.

Methods: chemical analyses.

Results: Ar and N inventories can be explained by a groundwater distillation model. Average release rate, by both phases, is 9.06 micromoles/mole H₂O for N, and 0.248 micromoles/mole H₂O for Ar. N and Ar distribution between aqueous and gaseous phase approaches equilibrium. There is no evidence for the presence of juvenile Ar or N in the hydrothermal fluids.

34 . A) Gen. Cat.--Active geothermal systems

B) Hackett, J. P., Jr.; Bischoff, J. L., 1973, New data on the stratigraphy, extent, and geologic history of the Red Sea Geothermal Deposits: Economic Geology, v. 68, no. 4, p. 553-564.

C) Purpose: to make a more detailed study of facies correlation, succession, and history of hydrothermal deposition in the Atlantis II deep, using the heretofore undescribed cores from the 1969 Wando River.

Methods: drill core studies, XRD, chemical analyses (XRF, AA), petrography, carbon isotopes.

Results: nine of the cores bottomed in basaltic bedrock underlying metalliferous sediments. C^{14} analyses of samples immediately overlying the basalt indicate a lower or maximum age of the deposits in the Atlantis II Deep of 25,000 years. The lowermost unit in the deep is represented by normal Red Sea carbonate sediments. Carbonate sedimentation in the Atlantis II Deep was continuous from 25,000 to 12,900 years B. P., with minor episodes of geothermal activity. Continuous geothermal activity in the Atlantis II Deep began approximately 12,900 years ago, and is continuing today.

35 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Lagache, M.; Sabatier, G., 1973, Distribution des éléments Na, K, Rb, et Cs à l'état de trace entre feldspaths alcalins et solutions hydrothermales à 650°C, 1 kbar: données expérimentales et interprétation thermodynamique: *Geochimica et Cosmochimica Acta*, v. 37, no. 12, p. 2617-2640.

C) Purpose: determine distribution data of alkali metals between minerals and hydrothermal waters.

Methods: petrography, XRD, emission photometry.

Results: in binary equilibria (an alkali (i) versus a feldspar that contains only one alkali (j)) distribution depends on the properties of feldspar (j) and the properties of the solid solution phase (feldspar(ij)). In ternary systems (an alkali (i) versus a solid solution feldspar (jk)), excess Gibb's free energy controls distribution. Distributions of Rb and Cs in albite-sanidine solid solution are consistent with this theory.

36 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Mazor, E.; Fournier, R. O., 1973, More on noble gases in Yellowstone National Park hot waters: *Geochimica et Cosmochimica Acta*, v. 37, no. 3, p. 515-525.

C) Purpose: analyze vapor phase in water before local separation of vapor takes place.

Methods: mass spectrometry.

Results: the gases originate from runoff water, saturated with air at 10 - 20°C. Rare gas retention varied from 3 to 87%. Heavy gases are enriched due to partial outgassing. No evidence for magmatic water contribution exists.

37 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Seward, T. M., 1973, Thio complexes of gold and the transport of gold in hydrothermal ore solutions: *Geochimica et Cosmochimica Acta*, v. 37, no. 3, p. 379-399.

C) Purpose: examine solubility of Au at high T and P.

Methods: AAS.

Results: maximum solubility occurs in neutral pH range, up to 225 mg/kg.

3 thio-gold complexes control solubility: $\text{Au}_2(\text{HS})_2\text{S}^{2-}$ in alkaline solution, $\text{Au}(\text{HS})_2^-$ in neutral solution, and $\text{Au}(\text{HS})^0$ in acid solution. Gold is probably transported as thio and chloro complexes in hydrothermal solutions.

38 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Helz, G. R.; Sinex, S. A., 1974, Chemical equilibria in the thermal spring waters of Virginia: *Geochimica et Cosmochimica Acta*, v. 38, no. 12, p. 1807-1820.

C) Purpose: examine equilibrium models for explaining chemistry of thermal spring water.

Methods: AAS, chemical analyses.

Results: 96-98% of the dissolved solids are accounted for by Ca^{2+} , Mg^{2+} , HCO_3^- , and SO_4^{2-} . Na^+ and K^+ are very low. Waters with $T < 25^\circ$ are undersaturated with respect to calcite and dolomite; those with $T > 25^\circ$ are in equilibrium with these 2 minerals. Precipitation of CaSO_4 along with aragonite may account for a constant calcium-sulfate activity product. Eh may be controlled by pyrite oxidation at depth.

39. A) Gen.Cat.--Hydrothermal systems

B) Seward, T.M., 1974, Equilibrium and oxidation potential in geothermal waters at Broadlands, New Zealand: American Journal of Science, v. 274, no. 2, p. 190-192.

C) Purpose: demonstrate the attainment of equilibrium in the Broadlands geothermal field.

Methods: calculations based on published data.

Results: average Eh of deep waters at Broadlands is -0.55 volts. The agreement of iron-sulfide mineralogy Eh estimates and those from equilibria involving S and C species indicates overall attainment of equilibrium between solute species and mineral phases.

40 . A) Gen. Cat.--Hydrothermal systems

B) Stoiber, R. E.; Rose, W. I., Jr., 1974, Fumarole encrustations at active Central American volcanoes: *Geochimica et Cosmochimica Acta*, v. 38, no. 4, p. 495-516.

C) Purpose: use fumarole deposits to learn about fumarole gas.

Methods: XRD, XRF, petrography, chemical analysis.

Results: most encrustations are composed primarily of sulfates. Most common minerals are: sulfur, hematite, halite, sylvite, gypsum, ralstonite, anhydrite, thenardite, and langbeinite. Deposits are zoned, in response to changing T and P_{O_2} around the vent. This zonation may be related to reaction of wallrock with fumarolic gases (H_2O , SO_2 , CO_2 , HCl, and HF).

41. A) Gen. Cat.--Geothermal system

B) Arnorsson, S. A.; Kononov, V. I.; Polak, B. G., 1975, Gases of Icelandic hydrothermal: Bulletin Volcanologique, v. 39, p. 2-14.

C) Purpose: to study the hydrothermal of Iceland through their discharged gases.

Methods: chemical analysis of gases found in collected hydrothermal waters along with temperatures of the waters when collected.

Results: the main hydrochemical types of hydrothermal are described as well as the regularities of their distribution. The origin of H₂ in certain hydrothermal is discussed.

42 . A) Gen. Cat.--Hydrothermal systems

B) Arnórsson, S., 1975, Application of the silica geothermometer in low temperature hydrothermal areas in Iceland: American Journal of Science, v. 275, no. 7, p. 763-784.

C) Purpose: ascertain use of silica geothermometry in geothermal exploration

Methods: calculations based on published data

Results: silica concentrations are controlled by chalcedony solubility if $T < 110^{\circ}\text{C}$, and by quartz solubility if $T > 180^{\circ}\text{C}$. Dissolved silica data fits neither quartz nor chalcedony solubility at $110^{\circ}\text{C} < T < 180^{\circ}\text{C}$. Calculated T's are minima, and represent the last equilibrium with quartz or chalcedony. Mixing with cold ground waters lowers pH's and may result in a too high temperature estimate.

43. A) Gen.Cat.--Hydrothermal systems

B) Blattner, P., 1975, Oxygen isotopic composition of fissure-grown quartz, adularia, and calcite from Broadlands Geothermal Field, New Zealand: American Journal of Science, v. 275, no. 7, p. 785-800.

C) Purpose: examine use of stable isotopy in geothermal exploration

Methods: mass spectrometry

Results: data allows correlation of a temperature of 275°C with

$$10^3 \ln \left[\left(\frac{O^{18}}{O^{16}} \right)_{\text{quartz}} / \left(\frac{O^{18}}{O^{16}} \right)_{\text{k-spar}} \right] = 3.3$$

Mineral isotopy can be used to quantitatively study subsurface zones of boiling, and determine hydrologic stability of a system by investigating equilibrium between waters and secondary minerals.

44 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Clayton, R. N.; Steiner, A., 1975, Oxygen isotope studies of the geothermal system at Wairakei, New Zealand: *Geochimica et Cosmochimica Acta*, v. 39, no. 8, p. 1179-1186.

C) Purpose: investigate changes in isotopic composition of wall rock and hydrothermal fluids due to interaction.

Methods: petrography, mass spectrometry.

Results: volcanic rocks experienced an O^{18} depletion of about 4%. Carbonates are in isotopic equilibrium with water and record higher fossil temperatures. New hydrothermal quartz is also in isotopic equilibrium with thermal waters.

45 . A) Gen. Cat.--Geothermal systems

B) Iwasaki, I., 1975, Geochemical indicators and seismic phenomena:

Bulletin Volcanologique, v. 39, no. 1, p. 82-90.

C) Purpose: to relate seismic activity to chemical changes at hot springs, fumaroles, geysers, ground waters and natural gases.

Methods: samples collected at various Japan geothermal areas were analyzed chemically and related to measured seismic activity.

Results: chemical changes of discharges have some positive correlation with seismic activity.

46 . A) Gen. Cat.--Geothermal systems

B) Markhinin, E. K.; Bozhkova, L. I., 1975, Dependence of the chemical composition of thermal waters upon seismic activity: Bulletin Volcanologique, v. 34, p. 104-111.

C) Purpose: to relate thermal waters to seismic activity.

Methods: correlating seismic activity to chemical analysis data of the thermal waters.

Results: chemical changes at the hot springs are given correlating them to seismic activity at the Mendeleev Volcano (Kunashir Island).

47. A) Gen. Cat.-- Geothermal systems

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B) Miller, T. P.; Barnes, I.; Patton, W. W., 1975, Geologic setting and chemical characteristics of hot springs in West Central Alaska: Journal of Research of the USGS, v. 3, no. 2, p. 149-162.

C) Purpose: analysis of hot springs in Alaska.

Methods: chemical and isotope analysis plus field relationships.

Results: springs are related to plutons in the area. Chemical analysis shows meteoric origin for most waters but some have high Cl, Na, K and Ca indicating larger rock-water interaction or different source of water. Temperatures of water were determined and extent of circulation of waters is discussed.

48. A) Gen. Cat.--Geothermal systems, active

B) Okubo, T.; Sakenoue, M., 1975, Radioactive disequilibrium of thorium series nuclides in hot spring deposits: *Geochemical Journal*, v. 9, no. 4, p. 221-226.

C) Purpose: to report the results of a study of the concentration of radium isotopes (^{226}Ra and ^{228}Ra) and thorium isotopes (^{232}Th , ^{230}Th , and ^{228}Th) in a calcium carbonate sinter cone and hokutolites.

Methods: gamma-ray spectrometry, radiochemical analyses (unspecified)

Results: The concentrations of ^{232}Th , ^{228}Ra and ^{228}Th (thorium series nuclides) in a sinter cone were 2.4×10^{-2} , 4.3×10^{-1} , and 7.1×10^{-1} dpm/g, respectively. It was confirmed that thorium series nuclides in this sample were not in radioactive equilibrium with their parent, ^{232}Th . Hokutolite samples collected recently showed higher radioactivities of ^{228}Ra , ranging from 9.6×10^4 to 2.8×10^4 dpm/g BaSO_4 . These values give a rate of deposition and an initial composition of the radionuclides in the hokutolite.

49 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Pampura, V. D.; Novikov, V. M., 1975, The Pauzhet hydrothermal system and the geochemistry of pore solutions from ore-formation zones in active volcanic regions: *Geochemistry International*, v. 12, no. 2, p. 262-271.

C) Purpose: examine role of pore fluids in ore genesis in volcanic regions.

Methods: wet chemical, flame photometry, AAS.

Results: clay zones are composed of kaolinite, montmorillonite, hydromica, sulfides, (pyrite and marcasite), opal, alunite, alpha-cristobalite and native sulfur. Subsurface pore solutions belong to the sulfate-chloride Mg-Ca type and have elevated levels of Cu, Zn, Li, Mo, Cd, and Ni. Maximum concentrations are proximal to the zones of rapid heat and mass transfer near points of emergence of fumaroles and condensate.

50. A) Gen. Cat.--Hydrothermal systems

B) Pampura, V. D., 1975, Heat and mass transfer in hydrothermal systems:

Geochemistry International, v. 12, no. 6, p. 135-144.

C) Purpose: consider heat and mass transfer for a system comprised of a hydrothermal solution and rock subject to mixed boundary conditions.

Methods: computer modelling

Results: there is a clear correlation between the geological position and the type of hydrothermal alteration, as well as the extent of heat and mass transfer. Vertical zoning in aureoles is related to the rate of heat or mass transfer. This is represented as a correlation between mean relative sizes of aureoles, and relative quantities of Cr, Pb, As, and Li in the aureoles.

51 . A) Gen. Cat.--Geothermal systems

B) Batzle, M. L.; Simmons, G., 1976, Microfractures in rocks from two geothermal areas: Earth and Planetary Science Letters, v. 30, p. 71-93.

C) Purpose: to analyze microfractures in the caprock of the geothermal systems to gain information on past history and current state of the system. Cores are from Dunes, Cal. and Raft River, Idaho.

Methods: electron microscopy, optical microscopy, and differential strain analysis.

Results: The model geothermal system has cold, dilute, meteoric water descending along one limb of a convecting cell and so increases temperature. As it does, it precipitates carbonates, sulfates, dissolved silica, K_2O , Na_2O , and other compounds. As the cell rises and cools it precipitates quartz, chalcedony adularia, pyrite and analcime. This way a cap rock is formed sealing the system. Since it is brittle it is subject to repeated fracturing. The system involves the interplay among the fractures, rocks and interstitial and fracture fluids. Both areas show multiple periods of fracturing. Both had fluid chemistries that varied with time and usually resulted in fracture sealing. The two areas differ in their specific fracture mineralogy caused by differences in bulk composition of rocks. Rock compressibilities indicate a low crack porosity even though large fractures are present in all samples. The low crack porosity is probably due to fracture sealing or fracturing being confined to a few large fractures.

52 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Brock, T. D.; Cook, S.; Petersen, S.; Mosser, J. L., 1976, Biogeochemistry and bacteriology of ferrous iron oxidation in geothermal habitats: *Geochimica et Cosmochimica Acta*, v. 40, no. 5, p. 493-500.

C) Purpose: characterize behavior of Fe in geothermal waters.

Methods: chemical analyses, XRD.

Results: the bacteria *Sulfolobus acidocaldarius* is able to oxidize large amounts of ferrous iron in hot, acid springs. However, rates vary widely. Oxidation did not occur at $T \geq 90^{\circ}\text{C}$, putting an upper temperature limit on this process. Reduction of ferric iron is probably the rate controlling reaction in this cycle. Sulfide content was too low to reduce ferric iron. Elemental S may be responsible for the reduction.

53 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Pampura, V. D.; Karpov, I. K.; Kazmin, L. A., 1976, Physicochemical evolution of a present day hydrothermal system (Pauzhetka hydrothermal system): *Geochemistry International*, v. 13, no. 2, p. 11-21.

C) Purpose: describe the evolution of thermal waters at Pauzhetka.

Methods: computer modelling using minimization of Gibbs free energy method.

Results: decrease in temperature (as fluids move upwards to surface) causes fluid pH to move away from neutrality, to either higher or lower pH. Reaction between solution and atmospheric CO₂ always causes an abrupt increase to pH of 8-9. CO₂ solubility increases with decreasing temperature, causing decrease in pH (in a closed system). Equilibrium H₄SiO₄ concentrations vary with P and T, but not with composition. Precipitation of silica can be accomplished in open or closed systems by a drop in temperature to 150°C.

54 . A) Gen. Cat.--Hydrothermal systems

B) Volfinger, M., 1976, Effect de la température sur les distributions de Na, Rb, et Cs entre la sonidine, la muscovite, la phlogopite et une solution hydrothermale sous une pression de 1 kbar: *Geochimica et Cosmochimica Acta*, v. 40, no. 3, p. 267-282.

C) Purpose: study the distribution of alkali elements in hydrothermal solutions and alteration minerals.

Methods: ion exchange.

Results: distributions are expressed as partition ratio:

$$P_x^{aq-m} = (x/k)^{aq} / (x/k)^m \quad \text{where } x \text{ is the alkali element.}$$

Generally, P decreases with increasing T. $\log P = f(1/T)$ is linear for Rb, but not Na and Cs. Generally, P does not depend on the alkali ion concentration in silicates. The distributions of Rb and Cs between phlogopite and muscovite can be used as geothermometers.

55 . A) Gen. Cat.--Geothermal systems, active

B) Bencini, A.; Duchi, V.; Martini, M., 1977, Geochemistry of thermal springs of Tuscany (Italy): Chemical Geology, v. 19, no. 3, p. 229-252.

C) Purpose: to study the geochemistry of the thermal springs of Tuscany.

Methods: chemical analyses (wet chemistry, AA, flame spectrophotometry, colorimetry, titration)

Results: the main reservoir for the deep aquifer is in the carbonate-anhydrite formation of Mesozoic age. The exothermic reaction of the anhydrite-gypsum transformation with an equilibrium temperature of about 40°C may be an important factor producing the heating of circulating solutions. From the chemical composition it is possible to find water of the same type when the origin is a more superficial one and the formations leached are Tertiary evaporites, but a lower Sr/SO₄ ratio often is an indication of the different genesis.

56. A) Gen. Cat.--Geothermal systems; metal zoning

B) Ewers, G. R.; Keays, R. R., 1977, Volatile and precious metal zoning in the Broadlands geothermal field, New Zealand: Economic Geology, v. 72, no. 7, p. 1337-1354.

C) Purpose: to document the distribution of Au, Ag, As, Sb, Tl, Bi, Se, Te, and Co in pool sinters and in total sulfide separates from two of the diamond drill holes.

Methods: chemical analyses (XRF), electron microprobe, fluid inclusions.

Results: the concentrations of volatile, precious, and major elements in sulfide concentrates from several Broadlands drill holes and a selection of discharge sinters have been documented and clearly confirm the existence of a crude metalliferous zoning. Higher concentrations of Tl, As, Au, Sb, and Fe are found near the surface of the field, whereas the concentrations of Bi, Se, Te, Ag, Pb, Cu, and Zn decrease with decreasing depth.

57 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Ewers, G. R., 1977, Experimental hot water-rock interactions and their significance to natural hydrothermal systems in New Zealand: *Geochimica et Cosmochimica Acta*, v. 41, no. 1, p. 143-150.

C) Purpose: ascertain whether trace elements are available for solution in an hydrothermal system.

Methods: INAA.

Results: As, Sb, Se, and S can be extracted in large quantities by waters at less than temperatures observed in geothermal fields in New Zealand.

The amount of Tl and Co leached was below the limits of detection.

58 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Kusakabe, M.; Robinson, B. W., 1977, Oxygen and sulphur isotope equilibria in the system $\text{BaSO}_4 - \text{HSO}_4^- - \text{H}_2\text{O}$ from 110 - 350°C and applications: *Geochimica et Cosmochimica Acta*, v. 41, no. 8, p. 1033-1040.

C) Purpose: investigate the attainment of isotopic equilibria in natural systems.

Methods: mass spectrometry, XRD.

Results: Oxygen isotope fractionation factors (α) in 1 m NaCl solution,

assuming $\alpha_{\text{CO}_2 - \text{H}_2\text{O}} = 1.0407$ at 25°C, are:

$$10^3 \ln \alpha_{\text{BaSO}_4 - 1\text{mNaCl}} = 2.64 \frac{(10^6)}{(T^2)} - 5.3 \pm 0.3$$

When corrected for ion hydration effects, in pure water, this becomes:

$$10^3 \ln \alpha_{\text{BaSO}_4 - \text{H}_2\text{O}} = 3.01 \frac{(10^6)}{(T^2)} - 7.3 \pm 0.1.$$

A barite-sulfide geothermometer is obtained by combining $\text{HSO}_4^- - \text{H}_2\text{S}$ and sulfide - H_2S calibration data.

59 . A) Gen. Cat.--Geothermal systems, active

B) Leeman, W. P.; Doe, B. R.; and Whelan, J., 1977, Radiogenic and stable isotope studies of hot-spring deposits in Yellowstone National Park and their genetic implications: *Geochemical Journal*, v. 11, no. 3, p. 65-74.

C) Purpose: to present Pb and Sn isotopic analyses of siliceous and carbonate hot-spring deposits in Yellowstone National Park, U.S.A., and similar analyses of sedimentary and volcanic rocks in that area in an attempt to trace the origin of thermal waters there.

Methods: Chemical analyses (unspecified), stable isotope studies, lead and strontium isotopic tracer studies.

Results: the hot-spring waters are dominated by meteoric water. The lead isotope data show that there is a sedimentary component of lead in all the hot spring deposits analyzed, including those inside the caldera limits. Either long lateral migration of waters are involved in the recharge of the springs or there must be sediment buried at some unknown depth beneath the volcanic rocks inside the caldera because no sediments are known at the surface. The high rainfall inside the limits of the caldera would favor sediments buried at depth.

60 . A) Gen. Cat.--Hydrothermal systems

B) McMurty, G.M.; Fan, P.W.; Coplen, T.B., 1977, Chemical and isotopic investigations of groundwater in potential geothermal areas in Hawaii: American Journal of Science, v. 277, no. 4, p. 438-458.

C) Purpose: examine groundwater chemistry to locate an exploration drill site.

Methods: wet chemical analyses, mass spectrometry.

Results: calculated temperatures from silica geothermometry range from 160°-275°C at the most promising site. Mixing with cooler groundwaters appears ubiquitous. Seawater intrusion disrupts equilibrium and tends to interfere with isotope and Na-K-Ca geothermometry.

61 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Nordstrom, D. K.; Jenne, E. A., 1977, Fluorite solubility equilibria in selected geothermal waters: *Geochimica et Cosmochimica Acta*, v. 41, no. 2, p. 175-188.

C) Purpose: test whether fluoride concentrations are controlled by fluorite solubility in hydrothermal systems.

Methods: calculations based on published data.

Results: fluorite solubility controls dissolved fluoride activity. Under-saturated waters have been diluted by non-thermal waters. Mathematical modelling has generated new thermodynamic constants for fluorite.

62 . A) Gen. Cat.—Hydrothermal systems

B) Norton, D.; Knapp, R., 1977, Transport phenomena in hydrothermal systems: the nature of porosity: American Journal of Science, v. 277, no. 8, p. 913-936.

C) Purpose: study controls on porosity.

Methods: calculations based on published data.

Results: rock porosity may be described by:

$$\phi_{\text{Total}} = \phi_{\text{Flow}} + \phi_{\text{Diffusion}} + \phi_{\text{Residual}}$$

In fractured rocks in hydrothermal systems, ϕ_{Total} ranges from 0.2 to 0.01; $\phi_{\text{diffusion}}$ ranges from 10^{-3} to 10^{-5} . Thus, most porosity around plutons is due to unconnected residual pores. Permeabilities of 10^{-14} characterize large areas of the crust.

63.A) Gen. Cat.--Hydrothermal systems

B) Norton, D.; Knight, J., 1977, Transport phenomena in hydrothermal systems:

cooling plutons: American Journal of Science, v. 277, no. 8, p. 937-981.

C) Purpose: mathematically model mass transport in pluton environments.

Methods: calculations based on published data.

Results: when rock permeabilities exceed 10^{-14} , convection predominates over conduction as the mechanism of heat transport. It is predicted that magmatic waters travel several kilometers on a time scale of hundreds of thousands of years. P-T changes along flow paths produce dramatic changes in solvent properties. Fluid/rock = 0.4 over the entire permeable portions of the systems.

64 . A) Gen. Cat.--Alteration studies

B) Ozima, M.; Saito, K.; Honda, M.; Aramaki, S., 1977, Seawater weathering effect on K-Ar age of submarine basalts: *Geochimica et Cosmochimica Acta*, v. 41, no. 4, p. 453-461.

C) Purpose: study argon loss and potassium addition in altered submarine basalts.

Methods: petrography, microprobe, mass spectrometry, step heating experiments.

Results: K content decrease toward interior of basalts; K-Ar age show a similar decrease in one sample but no change in the other. This could be accounted for by a simple diffusion model, depending on the time of initiation of K-diffusion.

65. A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Pampura, V. D.; Plyusnin, G. S.; Sandimirova, G. P., 1977, Sr isotope compositions for hot springs in Kamchatka: *Geochemistry International*, v. 14, no. 4, p. 83-87.

C) Purpose: elucidate the origin of hydrothermal systems in regions of current vulcanism

Methods: mass spectrometer.

Results: $^{87}\text{Sr}/^{86}\text{Sr}$ ranges from .7035 to .7070 for these thermal waters. Lower values ($^{87}\text{Sr}/^{86}\text{Sr} < .7043$) are associated with NaCl waters. Higher values represent mixing of NaCl waters with cold surface waters with a high ^{87}Sr content. Sea water is not an important constituent, and a juvenile source is assumed.

66 , A) Gen. Cat.—Active and semidormant hydrothermal systems

B) Shanks, W. C., III; Bischoff, J. L., 1977, Ore transport and deposition in the Red Sea geothermal system: a geochemical model: *Geochimica et Cosmochimica Acta*, v. 41, no. 10, p. 1507-1519.

C) Purpose: draw analogies between ancient and modern geothermal ore deposition.

Methods: calculations based on published data.

Results: the Red Sea hydrothermal fluid is highly saline and heated to $200 + ^\circ\text{C}$. NaSO_4^- and MgSO_4 dominate at T's up to 250° ; H_2S is kept at 2ppm by sulfate complexes. Metals are solubilized by chlorides and carried into the Atlantic II Deep. At lower T's, metals are precipitated as sulfides. The model is in good agreement with observed ore bodies.

67 . A) Gen. Cat.--Hydrothermal systems

B) Sokolova, N. T.; Khodakovskiy, I. L., 1977, The mobility of aluminum in hydrothermal systems: *Geochemistry International*, v. 14, no. 3, p. 105-112.

C) Purpose: examine the conditions and degree to which Al is mobile.

Methods: calculations based on published data.

Results: mobility of Al increases markedly with temperature. Al mobility is also a function of pH, reaching a minima at neutral pH's; however, the effect of elevated T's would predominate over pH and Al could be mobile at any pH. Al mobility in alkaline solutions is greatly reduced in the presence of K^+ .

68 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Zinder, S.; Brock, T. D., 1977, Sulphur dioxide in geothermal waters and gases: *Geochimica et Cosmochimica Acta*, v. 41, no. 1, p. 73-79.

C) Purpose: characterize the occurrence of SO_2 in hydrothermal systems at Yellowstone National Park.

Methods: gas chromatography, colorimetry (pararosaniline method), spectrophotometry, chemical analyses.

Results: SO_2 was found in small amounts in most springs studied, but never in gases, which generally contained H_2S . Volatilization of SO_2 is probably prevented by the low T's at Yellowstone National Park. Laboratory studies indicate that oxidation of H_2S is not accomplished at low pH. Bacteria associated with the springs do not seem to have an effect on H_2S ; oxidation to SO_2 is therefore organic.

69 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Arnórrson, S.; Grönvold, K.; Sigurdsson, S., 1978, Aquifer chemistry of four high-temperature geothermal systems in Iceland: *Geochimica et Cosmochimica Acta*, v. 42, no. 5, p. 523-536.

C) Purpose: report on chemical trends in hydrothermal fluids.

Methods: chemical analyses and computer calculations.

Results: salinity is highly variable (Cl varies from 20 to 19,000 ppm).

Unflashed reservoir waters are saturated with calcite; saline waters are saturated with anhydrite while fresh waters are undersaturated with this mineral. At a given T, the activity of one cation fixes the activities of all other cations including hydrogen. Thus, major element chemistry of the unflashed reservoir is controlled by 2 independent variables: T and Cl supply (Cl is not incorporated in geothermal minerals).

70 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Barnes, I.; Downes, C.J.; Hulston, J.R., 1978, Warm springs, South Island, New Zealand, and their potentials to yield laumontite: American Journal of Science, v. 278, no. 10; p. 1412-1427.

C) Purpose: investigate waters and gases from engeosynclinal environments.

Methods: XRD, petrography, AAS, wet chemical techniques, mass spectrometry.

Results: the springs are all supersaturated with laumontite and are usually in equilibrium with or undersaturated with albite and calcite.

Isotopy indicates waters are meteoric in origin. CO_2 partial pressures vary from 5.3×10^{-6} atm. to 1.4 atm. CO_2 is a dependent variable. Analcime and prehnite are not necessarily grade indicators, but rather may be products of different chemical conditions.

71 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Boulegue, J., 1978, Metastable sulphur species and trace metals (Mn, Fe, Cu, Zn, Cd, Pb) in hot brines from the French Dogger: American Journal of Science, v. 278, no. 10, p. 1394-1411.

C) Purpose: study the role of sulphur species in trace metal speciation.

Methods: AAS, wet chemical methods.

Results: organic matter is important in the transportation of reduced sulphur species. Concentrations of Mn and Zn are controlled by carbonates. Those of Fe, Cu, and Pb are controlled by sulfide (griegite, Fe_3S_4) precipitation.

72. A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Giggenbach, W. F., 1978, The isotopic composition of waters from the El Tatio geothermal field, Northern Chile: *Geochimica et Cosmochimica Acta*, v. 42, no. 7, p. 979-988.

C) Purpose: delineate the processes controlling the isotopic and chemical composition of thermal waters.

Methods: mass spectrometry, chemical analyses, use of published data.

Results: 4 controlling processes have been identified:

- 1) Deep dilution of a high chloride water by local groundwater.
- 2) Steam separation leading to isotopic shifts
- 3) Absorption of steam by shallow, moderate-temperature (160°C) water
- 4) Absorption of high H₂S steam by surface waters.

73. A) Gen. Cat.--Active geothermal systems

B) Henley, R. W.; McNabb, A., 1978, Magmatic vapor plumes and ground-water interaction in porphyry copper emplacement: *Economic Geology*, v. 73, no. 1, p. 1-20.

C) Purpose: to propose a fluid dynamic model for porphyry copper emplacement which focuses on the interaction of a bouyant low-salinity magmatic vapor plume with surrounding ground water.

Methods: Thermodynamic analyses.

Results: the plume model provides an interpretation of the characteristics of the deep zone of active geothermal systems and, with modification, may find application in the genetic interpretation of other families of ore deposit such as epithermal veins and submarine massive sulfides.

74 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Matsuhisa, Y.; Goldsmith, J. R.; Clayton, R. N., 1978, Mechanisms of hydrothermal crystallization of quartz at 250°C and 15 kbar: *Geochimica et Cosmochimica Acta*, v. 42, no. 2, p. 173-182.

C) Purpose: estimate isotopic equilibrium and mechanisms of isotopic exchange in the $\text{SiO}_2\text{-H}_2\text{O}$ system.

Methods: Mass spectrometry, SEM, XRD, three-isotope exchange method.

Results: Oxygen isotopic exchange between quartz and water yielded an equilibrium fractionation $\Delta^{18} = 9.0$ at 250°C and 15 kbar. Solution is the predominant mechanism; solid state diffusion is negligible.

Under these conditions, cristobalite inverts to sub-micron quartz crystals in minutes. The crystals are in isotopic disequilibrium with the water.

75 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Norton, D.; Panichi, C., 1978, Determination of the sources and circulation paths of thermal fluids: the Abano region, northern Italy: *Geochimica et Cosmochimica Acta*, v. 42, no. 8, p. 1283-1294.

C) Purpose: interpret data on the basis that fluid compositions are diagnostic of the geologic environment the fluid formed in.

Methods: mass spectrometry, chemical analyses.

Results: aquifer geometry forces convection of aqueous ions from limestone, dolostone, and anhydrite sources until water travels upward along high angle faults to the surface. Compositional variations indicate mixing of local meteoric water derived from the Alpine region.

76 . A) Gen. Cat.--Hydrothermal systems

B) Norton, D., 1978, Soucelines, source-regions, and pathlines for fluids in hydrothermal systems related to cooling plutons: *Economic Geology*, v. 73, no. 1, p. 21-28.

C) Purpose: to describe the concepts that permit quantitative description of the sources and flow paths of inert fluids which circulate in the vicinity of cooling plutons.

Methods: thermodynamic analyses.

Results: the redistribution of fluids in hydrothermal systems can be effectively estimated on the basis of numerical solutions to partial differential equations which simulate the cooling of a pluton.

77 . A) Gen. Cat.--Hydrothermal systems

B) Plyusnin, G. S.; Sandimirova, G. P.; Pakhol'chenko, Y. A.; Lomonosov, I. S.; Rzhechitsky, Y. P., 1978, Origin of recent hydrothermal solutions of the Baykal Rift Zone according to isotope ratios: *Geochemistry International*, v. 15, no. 5, p. 83-89.

C) Purpose: use Sr and D/H isotopy to examine hydrothermal solutions in the Baykal Rift Zone.

Methods: mass spectrometry.

Results: $^{87}\text{Sr}/^{86}\text{Sr}$ ranges from .70663 to .71247 and shows a strong decreasing trend towards the southwest, where seismicity and heat flow are at maxima. High Sr ratios also correspond to low chlorine contents, probably due to dilution with surface waters. Observed Sr ratios are the result of the mixing of 3 Sr systems: surface, crustal, and juvenile.

78 . A) Gen. Cat.-- Hydrothermal systems

B) Brecke, E. A., 1979, A hydrothermal system in the Midcontinent region:
Economic Geology, v. 74, no. 6, p. 1327-1335.

C) Purpose: to show that the Mississippi embayment syncline is a source for mineralizing solutions for several mineral districts around the periphery of the embayment.

Methods: field mapping, fluid inclusions, chemical.

Results: the hydrothermal system described in this paper contains all the elements necessary to produce several of the base metal deposits of the central craton.

79 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Richardson, C. K.; Holland, H. D., 1979, The solubility of fluorite in hydrothermal solutions, an experimental study: *Geochimica et Cosmochimica Acta*, v. 43, no. 8, p. 1313-1325.

C) Purpose: extend solubility measurements on fluorite to higher T's and in various solutions, and determine the stability constants for fluorite in these solutions.

Methods: XRD, AAS, microprobe.

Results: fluorite solubility increases with T up to 100°C in NaCl solution . Above this T, solubility reaches a maxima and drops off if NaCl < 1.0M, and increases continuously if NaCl > 1.0M. Solubility increases continuously with increasing KCl and CaCl₂ at any T and follows Debye-Hückel theory for KCl. In NaCl and CaCl₂ solutions, solubility increases more rapidly than predicted due to NaF⁰, CaF⁺, and Na₂F⁺ in solution. Common ion effect controls solubility in these solutions. Presence of HCl increases solubility.

80 . A) Gen. Cat.--Active and semidormant systems.

B) Richardson, C. K.; Holland, H. D., 1979, Fluorite deposition in hydrothermal systems: *Geochimica et Cosmochimica Acta*, v. 43, no. 8, p. 1327-1335.

C) Purpose: apply solubility data to the study of ore deposits.

Methods: calculations based on published data.

Results: fluorite precipitation can be forced by 1) drop in temperature, 2) dilution by meteoric waters and drop in temperature, 3) mixing of two fluids of different chemical composition, or, 4) an increase in fluid pH due to wall rock interaction.

81 . A) Gen. Cat.--Geothermal systems, active

B) Starinsky, A.; Katz, A.; Levitte, D., 1979, Temperature-composition-depth relationship in Rift Valley hot springs: Hammat Gader, northern Israel: Chemical Geology, v. 27, no. 3, p. 233-244.

C) Purpose: to propose a model for the origin of the Hammet Gader springs.

Methods: chemical analyses (AA, potentiometry, gravitometry)

Results: the chemical composition of the springs originated from the mixing of an ancient, Ca-chloridic, rift brine with present day meteoric waters. The water temperatures are dictated by the regional geothermal gradient, which is calculated for the investigated area from deep drilling data.

82 . A) Gen. Cat.--Hydrothermal systems

B) Barsukov, V. L.; Pek, A. A., 1980, Solution self-mixing in the production of hydrothermal vein deposits: *Geochemistry International*, v. 17, no. 6, p. 100-113.

C) Purpose: simulate movement of solution through geologic systems.

Methods: electrical hydrodynamic simulation.

Results: self-mixing results in the continuous production of chemically inhomogeneous solutions which are capable of reacting with each other. A regular spatial sequence of the 3 mass transfer mechanisms (infiltration, diffusion, and solution mixing) is characteristic of wall-rock interaction. Rhythmic variation in ores and metasomatites is characteristic of any hydrothermal vein deposit.

83 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) D'Amore, F.; Panichi, C.; 1980, Evaluation of deep temperatures of hydrothermal systems by a new gas geothermometer: *Geochimica et Cosmochimica Acta*, v. 44, no. 3, p. 549-566.

C) Purpose: use relative amounts of gases as a geothermometer.

Methods: calculations based on published data.

Results: the following relationship between reservoir temperature and relative concentrations of H_2S , CO_2 , CH_4 was derived:

$$t(^{\circ}C) = \frac{24775}{\alpha + \beta + 36.05} - 273$$

where:

$$\alpha = z \log \frac{CH_4}{CO_2} - 6 \log \frac{H_2}{CO_2} - 3 \log \frac{H_2S}{CO_2}$$

$$\beta = 7 \log P_{CO_2}$$

and concentrations are in % volume.

- 84 . A) Gen. Cat.--Active and semidormant hydrothermal systems
- B) Giggenbach, W. F., 1980, Geothermal gas equilibria: *Geochimica et Cosmochimica Acta*, v. 44, no 12, p. 2021-2032.
- C) Purpose: delineate the reactions and processes controlling the composition of New Zealand geothermal gas discharges.
- Methods: calculations based on published data.
- Results: composition of fluids from geothermal discharge indicates nearly complete equilibrium within the system H_2O , CO_2 , H_2S , N_2 , H_2 , NH_3 , and CH_4 . Graphite, anhydrite, pyrrhotite and magnetite do not take part in the overall equilibrium system. Gas reactions can be evaluated if temperature, pressure, and vapor-liquid ratios are known.

85 . A) Gen. Cat.--Geothermal system

B) Lambert, S. J.; Epstein, S., 1980, Stable isotope investigations of an active geothermal system in Valles Caldera, Jemez Mountains, New Mexico: Journal of Volcanology and Geothermal Research, v. 8, p. 111-129.

C) Purpose: to shed light on the geothermal processes at the Valles Caldera.

Methods: $^{18}\text{O}/^{16}\text{O}$, $^{13}\text{C}/^{12}\text{C}$ and D/H measurements were made on rocks and minerals from drill cuttings 0 - 1700 m depth.

Results: hydrothermal temperatures are estimated, origin of waters are discussed and alteration mineralogy is analyzed.

86 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Morgan, J. W.; Wandless, G. A., 1980, Rare earth element distribution in some hydrothermal minerals: evidence for crystallographic control: *Geochimica et Cosmochimica Acta*, v. 44, no. 7, p. 973-980.

C) Purpose: determine controls on REE distribution in hydrothermal minerals.

Methods: INAA, photon spectrometry.

Results: log REE abundance is a linear function of (ionic radius of major cation - ionic radius of REE)² for 3 minerals (anhydrite, barite, siderite).

Eu, however, is anomalously enriched in barite and depleted in siderite.

87.A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Pampura, V. D.; Plyusnin, G. S.; Sandimirova, G. P., 1980, Geochemical and isotopic composition of strontium in mineral forming solutions of the Pauzhetka hydrothermal system (southern Kamchatka): Geochemistry International, v. 17, no. 1, p. 57-70.

C) Purpose: examine isotopy of Sr in Pauzhetka thermal waters and sources of these waters.

Methods: mass spectrometry.

Results: $^{87}\text{Sr}/^{86}\text{Sr}$ ranges from .7033 to .7056 in deep NaCl springs, indicating that seawater does not contribute to this system. This ratio for the wall rock ranges from .702 to .705; thus, thermal waters may have inherited a $^{87}\text{Sr}/^{86}\text{Sr}$ of .703-.704 at the stratal reservoir level.

Isotopic composition of sulfate-bicarbonate-chloride waters ($^{87}\text{Sr}/^{86}\text{Sr} = .7036-.7067$) is explained by mixing of NaCl thermal waters with meteoric waters with a "marine" isotopic composition of .7095.

88 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Parry, W. T.; Ballantyne, J. M.; Bryant, N. C.; Dedolph, R. E., 1980,
Geochemistry of hydrothermal alteration at the Roosevelt Hot
Springs thermal area, Utah: Geochimica et Cosmochimica Acta, v. 44,
no. 1, p. 95-102.

C) Purpose: report chemistry of fluids and alteration minerals and discuss
equilibrium and mass transfer models of the alteration.

Methods: XRD, petrography, chemical analyses.

Results: the sodium chloride-acid sulfate water has altered igneous and
metamorphic rocks to alunite, opal, kaolinite, montmorillonite, muscovite,
sulfides, chlorite and calcite. Present water temperature is 25°C, and
discharge very low, but water temperature and discharge were much higher
in 1950 (85°C and 38 liter/min.). Alteration minerals and thermal solution
are not in equilibrium. Observation and calculation support a mass transfer
model where alteration is accomplished by 2 separate fluids at different
depths.

89 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Sakai, H.; Gunnlaugsson, E.; Tómasson, J.; Rouse, J. E., 1980, Sulphur isotope systematics in Icelandic geothermal systems and influence of seawater circulation at Reykjones: *Geochimica et Cosmochimica Acta*, v. 44, no. 8, p. 1223-1231.

C) Purpose: evaluate the effects of seawater circulation on sulphur isotope systematics.

Methods: mass spectrometry.

Results: $\delta^{34}\text{S}$ values for pyrite from altered basalts and aqueous sulfides from geothermal fluids range from 0 to 2.6%, close to those for post-glacial basaltic lavas. Geothermal fluids from fields with seawater contribution, however, have enrichments in ^{34}S of up to 8% (and decreasing with decreasing depth). Disequilibrium between sulfate and sulfide exists in all systems studied.

90. A) Gen. Cat.--Active and semidormant hydrothermal systems or Alteration studies

B) Tsuzuki, Y.; Suzuki, K., 1980, Experimental study of the alteration process of labradorite in acid hydrothermal solutions: *Geochimica et Cosmochimica Acta*, v. 44, no. 5, p. 673-683.

C) Purpose: determine relationships between pH and the formation of secondary minerals.

Methods: chemical methods, XRD, electron microscopy, electron diffraction, microprobe, infrared spectroscopy.

Results: amorphous silica formed when $M_{\text{HCl}} = 1$ and $M_{\text{HCl}} = .3$. At $M_{\text{Cl}} = .2$, amorphous silica was formed but replaced by kaolinite.

Alteration with $M_{\text{HCl}} = .003$ was minor. Rate of dissolution of labradorite is controlled by surface area and diffusion through the layer of alteration products. All experiments were conducted at 230° or 245°C.

91. A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Bird, D. K.; Norton, D. L., 1981, Theoretical prediction of phase relations among aqueous solutions and minerals: Salton Sea geothermal area: *Geochimica et Cosmochimica Acta*, v. 45, no. 9, p. 1479-1493.

C) Purpose: calculate values for ion activities and CO₂ fugacity in equilibrium with observed mineralogy in geothermal fluids.

Methods: thermodynamic calculations based on published data.

Results: cation activities (normalized to H⁺) decrease with increasing T at constant P, but increase with increasing P at constant T. Calculated values are in close agreement with measured concentrations. Empirical solute geothermometers based on data at = 250 - 300°C cannot be extrapolated to higher T's because $\Delta H_{P,T,r}^{\circ}$ and $\Delta V_{P,T,r}^{\circ}$ decrease dramatically at those temperatures due to extrema in the thermodynamic and electrostatic properties of the solvent.

92 . A) Gen. Cat.--Geothermal systems

B) Chadhury, H. M.; Chatterjee, S. N., 1981, Microearthquake survey in the hot springs area in Parbati Valley (Himachal Pradesh, India):
Journal of Volcanology and Geothermal Research, v. 9, p. 29-39.

C) Purpose: plotting of hydrothermal related earthquakes to gain data pertinent to exploiting geothermal energy.

Methods: seismic survey, chemical analysis of waters.

Results: some aspects of the hydrothermal system are described and discussed in addition to earthquake data.

93 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Elderfield, H.; Greaves, M. J., 1981, Strontium isotope geochemistry of Icelandic geothermal systems and implications for sea water chemistry: *Geochimica et Cosmochimica Acta*, v. 45, no. 11, p. 2201-2212.

C) Purpose: ascertain the possibility that the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of seawater is markedly influenced by high-temperature alteration reactions.

Methods: ion exchange, mass spectrometry, isotope dilution.

Results: Icelandic geothermal waters are mixes of meteoric and sea water.

Both Rb and K are enriched in geothermal waters; preferential leaching of Rb relative to K is indicated. Sr and Ca are also both enriched in geothermal water, Ca especially (3.5-4.3 x sea water). $^{87}\text{Sr}/^{86}\text{Sr}$ for geothermal fluids are higher than associated rock but lower than seawater. Hydrothermally altered rocks have been subjected to significant Sr isotopic contamination by seawater. Hydrothermal input has a minor effect on oceanic mass balance of Sr but may be important in controlling Sr isotopic composition of sea water.

94 . A) Gen. Cat.—Active and semidormant hydrothermal systems

B) Giggenbach, W. F., 1981, Geothermal mineral equilibria: *Geochimica et Cosmochimica Acta*, v. 45, no. 3, p. 393-410.

C) Purpose: use thermodynamics to predict mineral equilibria in geothermal systems.

Methods: calculations based on previously published data.

Results: geothermal fluid chemistry in New Zealand is primarily controlled by the conversion of plagioclase by CO_2 to clays and calcite with $\log P_{\text{CO}_2} = 15.26 - 7850/(t + 273.2)$, temperature in $^{\circ}\text{C}$. Observed mineral assemblages reflect conversion of unstable primary phases, through metastable phases, and eventually (in time and/or space) to stable secondary phases. These secondary mineral assemblages can be plotted on stability diagrams to evaluate mineral/fluid interaction conditions.

95 . A) Gen. Cat.--Geothermal systems

B) Goff, F. E.; Grigsby, C. C.; Trujillo, P. E.; Counce, D.; Kron, A.,
1981, Geology, water geochemistry and geothermal potential of the
Jemez springs area, Cañon De San Diego, New Mexico: Journal of
Volcanology and Geothermal Research, v. 10, p. 227-244.

C) Purpose: survey of the geothermal area for possible exploitation of
the geothermal energy.

Methods: chemical analysis of waters, study of well data and general
geology.

Results: chemical content of water indicate that hot springs are derived
from deep geothermal fluid. No hot aquifer was found above the Precambrian
basement but small volume localized reservoirs are indicated.

96 . A) Gen. Cat.--Geothermal systems

B) Martini, M.; Piccardi, G.; Cellini Legittimo, P., 1981, The effect of variations in rainfall on the chemical composition of Vulcano fumaroles (Italy): Bulletin Volcanologique, v. 44, no. 1, p. 109-113.

C) Purpose: to study the effect of rainfall on the composition of discharge from fumaroles in Italy's Vulcano.

Methods: chemical analysis was made of collected discharges from fumaroles from Vulcano, Italy during which time rainfall was measured and related to the fumarole activity.

Results: effects on the composition of the discharges was found to vary with rainfall and is discussed.

97 . A) Gen. Cat.--Geothermal systems, active

B) Pandley, C. Ch.; Raymahashay, B. C., 1981, Studies on some low-temperature East Indian Hot Springs: Chemical Geology, v. 34, no. 1/2, p. 113-129.

C) Purpose: to conduct a geochemical investigation of the Ragir-Monghyr hot spring belt.

Methods: chemical analyses (colorimetry, flame photometry, spectrophotometry), temperature and pH measurements, O isotopes.

Results: the springs represent recycled groundwater which descends to a hallow hot zone and is flushed out after rains. The residence time is too short for any significant rock-water interaction. The only products of rock alteration identified are kaolinite and iron oxide.

98 . A) Gen. Cat.--Active and Semidormant Geothermal Systems

B) Ward, S. H.; Ross, H. P.; Nielson, D. L., 1981, Exploration strategy for high-temperature hydrothermal systems in Basin and Range Province: American Association of Petroleum Geologists Bulletin, v. 65, no. 1, p. 86-102.

C) Purpose: summarize previous studies and present a strategy for geothermal resource exploration in the Basin and Range Province.

Methods: this paper is a literature review. Methods used in papers cited include: gravimetry, soil geochemistry and trace element surveys, hydrologic data collection, gravity methods, ground magnetic methods, aeromagnetic methods, magnetotelluric methods, electric resistivity, self-potential, passive and reflection seismic, thermal methods, flow tests, and geologic mapping.

Results: authors recommend a 15 phase exploration strategy designed to eliminate costs of bad well placement.

- 1) Literature search
- 2) District reconnaissance (initial mapping)
- 3) Prospect mapping
- 4) Prospect evaluation
- 5) System Modeling (conceptual)
- 6) Obtain air photos and base maps
- 7) Prospect delineation (detailed mapping)
- 8) System modeling (numerical)
- 9) Test drilling
- 10) Drilling evaluation
- 11) Structure delineation
- 12) System modeling (detailed numerical and conceptual)
- 13) Drilling
- 14) Production testing
- 15) Reservoir modeling and feasibility study.

99 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Armannsson, H.; Gislason, G.; Hauksson, T., 1982, Magmatic gases in well fluids aid the mapping of the flow pattern in a geothermal system: *Geochimica et Cosmochimica Acta*, v. 46, no. 2, p. 167-177.

C) Purpose: use chemical analyses of well fluids and physical measurements in wells to construct a model of the Krafla geothermal field, Northeast Iceland.

Methods: titration, spectrophotometry, AAS, alpha radioactivity counting, mass spectrometry.

Results: the system consists of a lower part that is affected by magmatic gases at a $T > 300^{\circ}\text{C}$, and an upper part at a $T \approx 200^{\circ}\text{C}$ that shows only minor magmatic effects. SO_2 removed on the way up, possibly by deposition of pyrite and pyrrhotite; remaining sulphur reaches the surface as H_2S .

100 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Arnórsson, S.; Sigurdsson, S.; Svavarsson, H., 1982, The chemistry of geothermal waters in Iceland. I. Calculation of aqueous speciation from 0° to 370°C: *Geochimica et Cosmochimica Acta*, v. 46, no. 9, p. 1513-1532.

C) Purpose: develop a method for calculating species in geothermal waters.

Methods: use measured and calculated data to write a computer program.

Results: a program in Fortran IV has been written to calculate the composition and aqueous speciation of geothermal waters, taking into account pH, Eh, and partial gas pressures. The program can be used to investigate changes in water composition due to boiling and degassing, and changes in solution/mineral equilibria.

101. A) Gen. Cat.--Hydrothermal systems

B) Barsukov, V. L.; Borisov, M. V., 1982, Simulating the geochemical consequences of hydrothermal solution automixing: Part 2. Mass transfer in areas of contraction of hydrothermal flow: *Geochemistry International*, v. 19, no. 5, p. 26-36.

C) Purpose: examine mass transfer during automixing through computer modeling.

Methods: computer modeling.

Results: type of fissure and proportions of mixing solutions, as well as initial solution composition, determine composition of vein filling.

Differences in mass of product of up to 3 orders of magnitude can be accounted for by degree of mixing. There may be little hydrothermal alteration at upper end of cycle.

102 . A) Gen. Cat.--Hydrothermal systems

B) Barsukov, V. L.; Borisov, M. V., 1982, Simulating the geochemical consequences of hydrothermal solution automixing. Part 3. Mass transfer in a system with several successive automixing cycles: *Geochemistry International*, v. 19, no. 6, p. 15-30.

C) Purpose: consider the behavior of solutions in several automixing cycles.

Methods: computer modelling.

Results: rhythmic automixing produces regular zoning, both in vein filling and in surrounding metasomatites. Entry of a single solution into a fissure can result in precipitation of more than one parageneses at different points in the vein. Geochemical barriers are more common than any other type in ore precipitation.

103 . A) Gen. Cat.--Geothermal systems

B) Brookins, D. G., 1982, Potassium, uranium, thorium radiogenic heat contribution to heat flow in the precambrian and younger silicic rocks of the Zuni and Florida Mountains, New Mexico (USA):
Journal of Volcanology and Geothermal Research, v. 13, p. 189-197.

C) Purpose: to shed light on anomalous heat flows in the Zuni and Florida Mountains.

Methods: chemical analysis, heat flow measurements.

Results: possible explanations for anomalous heat flows are detailed and discussed.

104 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Capuano, R. M.; Cole, D. R., 1982, Fluid-mineral equilibria in a hydrothermal system, Roosevelt Hot Springs, Utah: *Geochimica et Cosmochimica Acta*, v. 46, no. 8, p. 1353-1364.

C) Purpose: compare predicted and observed alteration mineralogy and evaluate mineral equilibria in deep reservoir fluid.

Methods: petrography, chemical analyses.

Results: calculations give a temperature of about 288°C for the reservoir source, compared with an observed T of 268°C. Calculated mineralogy, in equilibrium with fluid at -240°C corresponds with observed mineralogy; addition of mixed layer clays to this mineralogy is calculated and observed at T - 210°C. Presence of minerals that do not appear to be in equilibrium with fluid may be due to inadequate thermo-dynamic data, or these minerals may be in equilibrium with an earlier hydrothermal event.

105. A) Gen. Cat.--Geothermal systems, active

B) Clark, I. D.; Fritz, P.; Michel, F. A.; Souther, J. G., 1982, Isotope hydrogeology and geothermometry of the Mount Meager geothermal area: Canadian Journal of Earth Sciences, v.19, no. 7, p. 1454-1473.

C) Purpose: main focus is threefold: a) a detailed investigation of the recharge environment and subsurface flow path of the thermal waters through analyses of ^{18}O , ^2H , and ^3H concentrations; b) determination of residence times of the thermal waters, through the use of tritium and ^{14}C ; c) the application of a series of geothermometers aimed at determining reservoir temperatures.

Methods: chemical analyses

Results: it is concluded that these thermal waters are not deeply circulating and have not experienced temperatures in excess of 140°C .

106 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Giggenbach, W. F., 1982, Carbon-13 exchange between CO_2 and CH_4 under geothermal conditions: *Geochimica et Cosmochimica Acta*, v. 46, no. 2, p. 159-165.

C) Purpose: use carbon isotopy to evaluate minimum residence times and maximum cooling rates of fluids in a geothermal system.

Methods: calculations based on published data.

Results: $\log K = 11.16 - 10,190/T$ is the calculated rate constant for ^{13}C exchange between CO_2 and CH_4 at temperatures above 500°C . This allows the isotopic composition of these 2 gases to be used to determine initial composition and cooling rate of a rising geothermal fluid. Chemical equilibration between CH_4 and CO_2 probably proceeds about 100 times faster than isotopic equilibration.

107. A) Gen. Cat.--Geothermal systems

B) Mazar, E.; Thompson, J. M., 1982, Evolution of geothermal fluids deduced from chemistry plots: Yellowstone National Park (USA): Journal of Volcanology and Geothermal Research, v. 12, p. 351-360.

C) Purpose: to show that a simple set of graphs can provide an overall picture and understanding of geochemical processes of a geothermal area.

Methods: chemical analysis of geothermal waters and gases is plotted in various graphs.

Results: similarity of hot springs in the area is shown, their origin is discussed and depth of secondary reactions is noted.

108 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Ohmoto, H.; Lasaga, A. C., 1982, Kinetics of reactions between aqueous sulfates and sulfides in hydrothermal systems: *Geochimica et Cosmochimica Acta*, v. 46, no. 10, p. 1727-1745.

C) Purpose: establish rate law for S isotopic reactions, obtain rate constants, and evaluate mechanisms of these reactions.

Methods: literature review, use of Barnes-type rocking autoclave and chemical techniques.

Results: Rate law:

$$\ln \frac{\alpha^e - \alpha}{\alpha^e - \alpha^0} = -kt (\sum \text{SO}_4^{2-} + \sum \text{S}^{2-})$$

where t = time and α^0 , α , and α^e are fractionation factors at $t = 0$, the end of the experiment, and at equilibrium, respectively. Rates of reaction between sulfates and sulfides are essentially identical to isotopic reactions since the same oxidation and reduction occurs in each. Rate constants are f (T, pH). Mixing of solutions of varying Eh accounts for observed fractionation in hydrothermal deposits.

109 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Patterson, C. S.; Slocum, G. H.; Busey, R. H.; Mesmer, R. E., 1982, Carbonate equilibria in hydrothermal systems: first ionization of carbonic acid in NaCl media at 300°C: *Geochimica et Cosmochimica Acta*, v. 40, no 9, p. 1653-1663.

C) Purpose: determine effect of salt on the first ionization of carbonic acid to evaluate the solubility limits of carbonates in solutions where pH is controlled by aluminosilicates.

Methods: use of flowing emf cell with hydrogen electrodes.

Results:

- 1) Carbonic acid becomes weaker as temperature increases, salt concentration decreases, and/or pressure decreases.
- 2) There is a lack of data above 300°C.
- 3) Use of this data can be applied to calculating pH dependencies.
- 4) $\Delta \bar{C}_p$ and $\Delta \bar{V}$ are approximately independent of salt concentration.
- 5) pH of CaCO₃-saturated, constant P (12 bars) solution increases from 5.1-5.5 between T = 100° - 300°C.

110 . A) Gen. Cat.--Active and Semidormant Geothermal Systems

B) Ross, H. P.; Nielson, D. L.; Moore, J. N., 1982, Roosevelt Hot Springs geothermal system, Utah - case study: American Association of Petroleum Geologists Bulletin, v. 66, no. 7, p. 876-902.

C) Purpose: summarize geological, geophysical, and geochemical data and present a strategy for resource exploration at Roosevelt Hot Springs.

Methods: a literature review.

Results: authors recommend a 5-stage exploration strategy for Roosevelt Hot Springs (may be applicable to other hot springs):

- 1) Literature study
- 2) Geologic mapping
- 3) Thermal gradient measurements
- 4) Dipole-dipole resistivity
- 5) Drilling

111 . A) Gen. Cat.--Active and semidormant geothermal systems.

B) Seyfried, W. E., Jr.; Mottl, M. J., 1982, Hydrothermal alteration of basalt by seawater under seawater dominated conditions: *Geochimica et Cosmochimica Acta*, v. 46, no. 6, p. 985-1002.

C) Purpose: characterize the solution chemistry and alteration mineralogy of basalt-seawater systems for reactions under seawater dominated conditions.
Methods: use of Dickson hydrothermal apparatus, XRD, colorimetry, flame and flameless AAS, DC plasma source optical emission spectrometry (DC-PES)
Results: at 300°C, basalt glass removed nearly all available Mg^{2+} from seawater and was converted into mixed layer clays, anhydrite, and minor hematite. Fe, Mn, and Zn were released into solution. When exposed to greater quantities of water, leaching of heavy metals was increased. Most cations became mobilized; V, Cr, and Ni are exceptions.

112 . A) Gen. Cat.--Geothermal systems

B) Smith, D. L.; Dees, W. T., 1982, Indicators of low temperature geothermal resources in northern Louisiana and central Mississippi: Journal of Volcanology and Geothermal Research, v. 14, p. 389-393.

C) Purpose: to describe a geothermal area on the Gulf Coast Plain.

Methods: heat flow measurements.

Results: an area with subsurface temperatures exceeding 50°C is inferred.

113 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Stauffer, R. E., 1982, Fluorapatite and fluorite solubility controls on geothermal water in Yellowstone National Park: *Geochimica et Cosmochimica Acta*, v. 46, no. 3, p. 465-474.

C) Purpose: show that previously reported PO_4 -P concentrations in Yellowstone geothermal waters are close to saturation with apatite and hottest spring waters are undersaturated with CaF_2 .

Methods: use of previously published data in thermodynamic calculations.

Results: near-boiling high-Cl waters are at or near saturation with fluorapatite. Hot diluted waters show undersaturation with respect to fluorapatite. Likewise, geothermal waters are undersaturated with respect to fluorite. The apparent disequilibrium may reflect equilibration with higher T water in deeper reservoirs.

114 . A) Gen. Cat.--Hydrothermal systems

B) Subzhiyeva, T. M.; Volkov, I. I., 1982, Thiosulfites and sulfites in thermal and hydrothermal waters: *Geochemistry International*, v. 19, no. 4, p. 94-98.

C) Purpose: examine the oxidation of S in natural waters.

Methods: wet chemical

Results: sulfite can correlate either positively or negatively with H_2S content. When both are high, they are probably the product of sulfate reduction. If H_2S is high but sulfite concentration is low, sulfites are probably the product of oxidation. Sulfite can also be formed through bacterial sulfate reduction.

115 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Torgerson, T.; Jenkins, W. J., 1982, Helium isotopes in geothermal systems:

Iceland, The Geysers, Raft River, and Steamboat Springs: *Geochimica et Cosmochimica Acta*, v. 46, no. 5, p. 739-748.

C) Purpose: to use helium isotope compositions of hydrothermal fluids to evaluate local tectonic environment and infer a source for thermal anomalies.

Methods: mass spectrometry.

Results: He-isotope signature can be used to identify source of geothermal

fluids: Hotspots: $R = 14-25 (R_a)$

Spreading centers: $R \approx 9 (R_a)$

Subduction zones: $R = 2-9(R_a)$

Crustal production: $R \ll R_a$

R_a = atmospheric ratio

116 . A) Gen. Cat.--Geothermal systems

B) Vakin, E. A.; Nikitina, L. P.; Shapar; Taran, 1982, Studies on volcanic gases and gases from hydrothermal fields in Kamchatka: Bulletin Volcanologique, v. 45, no. 3, p. 211-216.

C) Purpose: to describe work done on geothermal fields in Kamchatka.

Methods: gas samples collected in the field are analyzed by a variety of chemical methods.

Results: the paper describes the main lines of investigation for the volcanic and geothermal research in Kamchatka.

117 . A) Gen. Cat.--Geothermal systems

B) Vidal, F. V.; Welhan, J.; Vidal, V. M. N., 1982, Stable isotopes of helium, nitrogen and carbon in a coastal submarine hydrothermal system: Journal of Volcanology and Geothermal Research, v. 12, p. 101-110.

C) Purpose: to shed light on the hydrothermal system at Ensenada, Baja California.

Methods: gas samples were analyzed by gas chromatography and isotopes by mass spectrometer.

Results: chemical analysés are given and origins for components are discussed.

118 . A) Gen. Cat.--Geothermal systems

B) Younker, L. W.; Kasameyer, P. W.; Tewhey, J. D., 1982, Geological, geophysical and thermal characteristics of the Salton Sea geothermal field, California: Journal of Volcanology and Geothermal Research, v. 12, p. 221-258 .

C) Purpose: to describe characteristics of the Salton Sea geothermal field.

Methods: geological and geophysical

Results: description of rock structure and thermal gradient is given as well as discussion of interpretation of data to explain convection.

119. A) Gen. Cat.--Active and semidormant geothermal systems

B) Arnórsson, S.; Gunnlaugsson, E.; Svavarsson, H., 1983, The chemistry of geothermal waters in Iceland. II. Mineral equilibria and independent variables controlling water compositions: *Geochimica et Cosmochimica Acta*, v. 47, no. 3, p. 547-566.

C) Purpose: consider all major elements and overall equilibrium conditions in the temperature range 18-260°C.

Methods: spectrophotometric, AAS, XRF, titration, ion sensitive electrode.

Results: equilibrium is maintained for or closely approached with respect to all major components in Icelandic geothermal systems in the T range of 50-250°C. Controlling variables are T, and availability of chloride. Effect of P is insignificant. Given T and chloride concentration, the chemistry of these waters can be predicted at least as accurately as predicting thermodynamic properties of minerals. This predictability may be due to the small changes of free energy involved in transformation of one alteration mineral to another.

120 . A) Gen. Cat.—Active and semidormant geothermal systems

B) Arnórsson, S.; Gunnlaugsson, E.; Svavarsson, H., 1983, The chemistry of geothermal waters in Iceland. III. Chemical geothermometry in geothermal investigations: *Geochimica et Cosmochimica Acta*, v. 47, no. 3, p. 567-577.

C) Purpose: develop better accuracy in geothermometers, ascertain usefulness of known geothermometers.

Methods: use of data from 24 drill holes for chalcedony geothermometry and 27 drill holes for Na-K geothermometry. Data from 15 holes was used for CO₂ geothermometry. Method of analysis of concentrations of Na, K, SiO₂, CO₂ was not described.

Results: Na-K-Ca geothermometry is inferior to Na-K geothermometry in Icelandic basaltic terrain at all temperatures. New T functions are:

$$T(^{\circ}\text{C}) = \frac{1112}{4.19 - \log \text{SiO}_2} - 273.15 \quad (25 - 180^{\circ}\text{C})$$

$$T(^{\circ}\text{C}) = \frac{933}{0.993 + \log \text{Na/K}} - 273.15 \quad (25 - 250^{\circ}\text{C})$$

Concentrations in ppm

A CO₂ geothermometer is proposed as follows:

$$\log \text{CO}_2 = 37.43 + 73192/T - 11829 \cdot 10^3 / T^2 + 0.18923T - 86.187 \cdot \log T$$

CO₂ concentration is analyzed in steam in moles/kg; T is in ^oK.

121 . A) Gen. Cat.--Active and semidormant hydrothermal systems (exp. analog)

B) Becker, K. H.; Cemic, L.; Langer, K. E. O. E., 1983, Solubility of corundum in supercritical water: *Geochimica et Cosmochimica Acta*, v. 47, no. 9, p. 1573-1578.

C) Purpose: support theoretical calculations with experimental data.

Methods: weight loss method in cold seal apparatus or piston cylinder.

Results: corundum solubility increases with pressure (increasing density of supercritical water). Solubility data fits:

$$S_{(\text{ppm Al}_2\text{O}_3)} = -12.37 + 7.24 \cdot P(\text{kbar})$$

$r = .9963$

122 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Keith, T. E. C.; Thompson, J. M.; Mays, R. E., 1983, Selective concentration of cesium during hydrothermal alteration, Yellowstone National Park, Wyoming: *Geochimica et Cosmochimica Acta*, v. 47, no. 4, p. 795-804.

C) Purpose: determine sources and sinks for cesium in hydrothermal systems.

Methods: standardized emission d.c. arc spectrography, AAS, AES, titration.

Results: Cs is unequivocally more abundant in analcime-bearing, rather than clinoptilolite-bearing zones, although clinoptilolite zones have above background Cs concentrations. Adularia Cs concentrations fall within the background range. Addition of Cs to analcime occurs as the mineral forms during hydrothermal alteration; Cs is not exchanged for other cations later. Source of Cs may be local rocks (tuffs, rhyolites) or the roof zone of the underlying magma chamber.

123 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Kiyosu, Y.; Kurahashi, M., 1983, Origin of sulphur species in acid sulfate-chloride thermal water, northeastern Japan: *Geochimica et Cosmochimica Acta*, v. 47, no. 7, p. 1237-1245.

C) Purpose: disclose the origin of S-species in acid-chloride thermal waters along with their chemical and isotopic abundances.

Methods: titration, gravimetric analysis, mass spectrometry.

Results: $\delta^{34}\text{S}$ tends to increase with decreasing SO_4/Cl . This may be due to $\text{SO}_4/\text{H}_2\text{S}$ variation with variation in f_{O_2} in volcanic emanations. $\delta^{34}\text{S}$ increase could also be explained by deposition of light S Ψ within the ground, as is common in volcanic and geothermal areas. S/Cl is 4~7. Origin of S species in these springs is likely related to volcanic activity.

124 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Mazar, E.; van Everdingen, R. O.; Krouse, H. R., 1983, Noble-gas evidence for geothermal activity in a karstic terrain: Rocky Mountains, Canada: *Geochimica et Cosmochimica Acta*, v. 47, no. 6, p. 1111- 1115.

C) Purpose: use noble gases to determine sources and pathways of hydrothermal water.

Methods: water from 9 springs was analyzed by mass spectrometry.

Results: Ne, Ar, Kr, and Xe in these waters are of atmospheric origin. He and Rn are high and this is explained by the contribution of decaying U and Th in the country rock. Depletion in atmospheric noble gases at some sites indicates a residual geothermal liquid contribution. Noble gas data can be used to support other data in determining the degree of karst influence on a spring.

125 . A) Gen. Cat.--Geothermal systems

B) McDowell, S. D.; Elders, W. A., 1983, Allogenic layer silicate minerals in borehole Elmore #1, Salton Sea Geothermal Field, California: American Mineralogist, v. 68, no. 11 and 12, p. 1146-1159.

C) Purpose: to briefly discuss several examples of metastable layer silicates and the reactions that might control their formation.

Methods: petrography, electron microprobe.

Results: reaction among the various coarse grained layer silicates in the geothermal system is strongly dependent on kinetic factors, and must be considered on a site-by-site basis.

126 . A) Gen. Cat.--Active and semidormant hydrothermal systems or permeability studies

B) Moore, D. E.; Morrow, C. A.; Byerlee, J. D., 1983, Chemical reactions

accompanying fluid flow through granite held in a temperature gradient:

Geochimica et Cosmochimica Acta, v. 47, no. 3, p. 445-453.

C) Purpose: determine the effectiveness of granite in containing radionuclides in the event of canister leakage.

Methods: petrography, electron microprobe permeability tests using deionizing distilled water on granite cores in a temperature gradient imposed by a heater coil in a central drilled hole (T ranged from 300°C to 80°C at the outside of the core). Chemical analyses by AAS, spectrophotometric analysis, ion chromatography.

Results: permeability was reduced with time along the temperature gradient.

Mechanism appears to be solution of minerals at high T and redeposition in fractures and along grain boundaries at low T. T and flow rate control the mass transfer. The mineral that was most likely reprecipitated was quartz or some other silica phase.

127. A) Gen. Cat.--Active and Semidormant Hydrothermal Systems

B) Rimstidt, J. D.; Cole, D. R., 1983, Geothermal mineralization I: The mechanism of formation of the Beowawe, Nevada, siliceous sinter deposit: American Journal of Science, v. 283, no. 8, p. 861-875.

C) Purpose: discuss a model for the formation of this deposit.

Methods: calculations based on published data.

Results: sinter formation involved 3 steps: 1) Saturation with quartz at high T and precipitation as fluids rose to surface and cooled; 2) formation of a colloidal suspension of amorphous silica; 3) cementation of colloids by amorphous silica. 5.58×10^{14} kg of geothermal fluid is calculated to have been necessary to account for this deposit.

128 . A) Gen. Cat.—Active geothermal systems

B) Bird, D. K.; Schiffman, P.; Elders, W. A., Williams, A. E.; McDowell, S. D.,
1984, Calc-silicate mineralization in active geothermal systems:
Economic Geology, v. 79, no. 4, p. 671-695.

C) Purpose: to summarize the distributions, occurrences, compositional characteristics, and thermodynamic relations of calc-silicates in explored geothermal systems.

Methods: petrographic study of drill cores, thermodynamic analyses.

Results: Mineral assemblages and zoning patterns found in the upper 3km of the Earth's crust in areas of active geothermal activity are similar to phase relations reported in low-pressure regional and contact metamorphic rocks.

129 . A) Gen. Cat.--Geothermal systems

B) Cole, D. R.; Ravensky, L. I., Hydrothermal alteration zoning in the Beowawe Geothermal System, Eureka and Lander Counties, Nevada; 1984: Economic Geology, v. 79, no. 4, p. 759-767.

C) Purpose: to describe the alteration mineralogy from the various wells, and to define alteration patterns and metal zoning characteristics of the reservoir rocks.

Methods: Petrographic study of drill cuttings, XRD study of drill cuttings.

Results: Miocene diabase dikes acted not only as feeders for the overlying basalt and andesite but also were local heat sources responsible for driving fluid convection which produced some of the observed alteration and trace element patterns.

130 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) D'Amore, F.; Gionelli, G., 1984, Mineral assemblages and oxygen and sulphur fugacities in natural water-rock interaction processes: *Geochimica et Cosmochimica Acta*, v. 48, no. 4, p. 847-857.

C) Purpose: determine fugacities of S_2 and O_2 gases over a range of temperatures (150° - 350° C).

Methods: theoretical thermodynamic calculations.

Results: above 200° C the assemblage most consistent with observed O_2 and S_2 fugacities is : epidote, chlorite, K-spar, quartz, and pyrite.

Salton Sea shows equilibrium between rocks and brine.

The Geysers shows minerals that must have been produced at an earlier stage when water had temperature $\gt 320^\circ$ C. A similar process may have occurred at Larderello.

131 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Estep, M. L. F., 1984, Carbon and hydrogen isotopic compositions of algae and bacteria from hydrothermal environments, Yellowstone National Park:
Geochimica et Cosmochimica Acta, v. 48, no. 3, p. 591-599.

C) Purpose: use C and H isotopy to determine whether recent algae and bacteria can serve as analogs for ancient forms of life (ex: Precambrian stromatolites).
Methods: isotope ratios were determined by methods reported in Estep, 1981. CO₂ concentrations in hydrothermal water were measured by gas-sensing, specific-ion electrode. Eh was measured in a Fisher Accumat pH/mV meter.
Results: isotope compositions vary due to inorganic C concentration, temperature pH and species of bacteria or algae. Similarities between these hot springs and Precambrian stromatolites are numerous: 1) CO₂ levels, 2) isotopic compositions of life forms.

132 . A) Active and Semi-dormant Geothermal Systems

B) Halfman, S. E.; Lippman, M. S.; Zelwer, R.; Howard, J. H., Geologic interpretation of geothermal fluid movement in Cerro Prieto Field, Baja California, Mexico: American Association of Petroleum Geologists Bulletin, v. 68, no. 1, p. 18-30, 1984.

C) Purpose: develop a model of geothermal fluid flow in the Cerro Prieto field prior to exploration (1973).

Methods: interpretation of well log data (γ , SP, laterolog-8, med. induction, deep induction, short normal resistivity, long normal resistivity, compensated formation density, dipmeter, lithologic). Construction of temperature profiles.

Results: downhole T profiles and well production intervals in conjunction with a geologic model allowed postulation of geothermal fluid flow paths at Cerro Prieto. Movement is controlled by stratigraphic and structural features. This method can be used to identify natural fluid flow patterns, assist in assessing recharge capacity, and in planning optimal development.

133 . A) Gen. Cat.--Geothermal energy

B) Lewis, T., 1984, Geothermal energy from Penticton Tertiary outlier, British Columbia: an initial assessment: Canadian Journal of Earth Sciences, v. 21, no. 2, p. 181-188.

C) Purpose: to make an initial evaluation of the geothermal potential, based on geological structure and geothermal data.

Methods: heat flow measurements.

Results: A hot-water resource exists at the bottom of a Tertiary basin filled with insulating layers of volcanics and sediments. The thermal conductivity of the sediments ($1.67 - 1.95 \text{ wk}^{-1} \text{ m}^{-1}$) is lower than that of most metamorphic and magmatic rocks. The apparent availability of water within the basin and the high heat flow support the possibility of locating a hot-water resource in the basin.

134 . A) Gen. Cat.--Active and semidormant geothermal systems

B) Lyon, G. L.; Hulston, S. R., 1984, Carbon and hydrogen isotopic compositions of New Zealand geothermal gases: *Geochimica et Cosmochimica Acta*, v. 48, no. 6, p. 1161-1171.

C) Purpose: evaluate carbon and hydrogen isotopes for their origin and usefulness as geothermometers.

Methods: mass spectrometry.

Results: 1) $\delta^{13}\text{C}$ suggests a correlation with reservoir temperatures; however, temperatures derived from isotope data are 100-200°C higher than measured. This could be due to a) maturation of hydrocarbons, or, b) slow isotopic equilibrium fractionation. 2) $\text{H}_2\text{-H}_2\text{O}$ isotopic exchange appears to be the best geothermometer of the hydrogen systems ($\text{H}_2\text{-H}_2\text{O}$, $\text{H}_2\text{-CH}_4$, $\text{CH}_4\text{-H}_2\text{O}$). Again, temperatures estimated from isotopic data are higher than those measured. This may be caused by "frozen" equilibrium giving T at greater depth or corrosion of steel casings.

135 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Moorby, S. A.; Cronan, D. S.; Glasby, G. P., 1984, Geochemistry of hydrothermal Mn-oxide deposits from the S. W. Pacific island arc: *Geochimica et Cosmochimica Acta*, v. 48, no. 3, p. 433-441.

C) Purpose: describe morphology, mineralogy, and composition of Tonga-Kermadec ridge deposit, and discuss their geochemistry and origin.

Methods: Phillips diffractometer (Fe K α radiation), chemical analyses using ARL 34000 spectrometer, SEM.

Results:

- 1) Mn-oxide crust on Tonga Kermadec ridge are similar to others from MOR, but have developed on sediment or talus rather than bedrock.
- 2) Co, Ni, Cu, V, and some Fe is thought to have been scavenged from seawater as Mn precipitated.
- 3) Enrichments in Li, Zn, Mo, and possibly Cd, are probably due to hydrothermal supply.
- 4) This ridge shows more chemical variability than MOR hydrothermal deposits.

136 . A) Gen. Cat.--Active and semidormant hydrothermal systems.

B) Ragnarsdóttir, K. V.; Walther, S. V.; Arnórsson, S, 1984, Description and interpretation of the composition and alteration mineralogy in the geothermal system, at Svartsengi, Iceland: *Geochimica et Cosmochimica Acta*, v. 48, no. 7, p. 1535-1553.

C) Purpose: correlate solution chemistry, whole rock composition, and authigenic minerals within a geothermal system.

Methods: XRF, XRD, AAS, titration.

Results: alteration phases are at or close to equilibrium with fluid; primary phases are not. Mass transfer models have wide applicability in study of geothermal systems, although fluid flow modeling is also necessary.

137 . A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Reed, M.; Spycher, N., 1984, Calculation of pH and mineral equilibria in hydrothermal waters with application to geothermometry and studies of boiling and dilution: *Geochimica et Cosmochimica Acta*, v. 48, no. 7, p. 1479-1492.

C) Purpose: discuss methods of calculating properties of high-T/P aqueous solutions, including pH, Eh, f_{O_2} , f_{CO_2} , and ion activities, and present some applications of these methods.

Methods: mathematical techniques using mass action equations, mass balance equations, and redox equilibria.

Results: expressions were obtained that can be used to determine a) existence of equilibrium between solution and host rock, b) probable minerals in equilibrium assemblage, c) temperature of equilibrium.

The results are applied to several geothermal systems worldwide. Geothermal waters tend to approach equilibrium with a subsurface mineral assemblage.

138 . A) Gen. Cat.--Geothermal areas, active

B) Tanaka, K.; Koizumi, M.; Seki, R.; Ikeda, 1984, Geochemical study of Arima hot-spring waters, Hyogo, Japan, by means of tritium and deuterium: Geochemical Journal, v. 18, no. 4, p. 173-180.

C) Purpose: to measure tritium, deuterium and chloride concentrations in the Arima hot spring waters in an attempt to determine their origin and subsurface behavior.

Methods: O and H isotopes.

Results: T-D-Cl⁻ relationships clearly indicate that the saline brine of deep origin (T=0 TR, $\delta D = -30^{\circ}/\text{oo}$ and Cl⁻ = 43g/L) is mixed with young meteoric water having T=30 TR, D = $-50^{\circ}/\text{oo}$ and Cl⁻ = 0. g/L in varying proportions to form a group of high chloride hot spring waters.

139 . A) Gen. Cat.--Active and semi-dormant hydrothermal systems

B) Varekamp, J. C.; Buseck, P. R., 1984, The speciation of mercury in hydrothermal systems, with applications to ore deposition: *Geochimica et Cosmochimica Acta*, v. 48, no. 1, p. 177-185.

C) Purpose: examine the speciation of Hg in hydrothermal fluids.

Methods: primarily a review of existing literature on hydrothermal systems.

Activity diagrams and concentration vs. temperature are calculated.

Results: Hg^0 in solution is promoted by 1) increasing pH, temperature, or, 2) decreasing ΣS , ionic strength, $p\text{O}_2$. Hg^0 readily enters a vapor phase if one develops from the fluid. Cinnabar is precipitated if Hg^0 is oxidized to Hg^{2+} or under acidic conditions. Cinnabar + pyrite and cinnabar + hematite are both common, and liquid Hg^0 will coexist with all Fe sulfides and oxides; however, Hg^0 + cinnabar can be unstable. HgCl can form in saline waters.

140. A) Gen. Cat.--Geothermal systems, active
- B) Yoshida, Y., 1984, Origin of gases and chemical equilibrium among them
in steams from Matsukawa geothermal area, Northeast Japan: *Geochemical
Journal*, v. 18, no. 4, p. 195-202.
- C) Purpose: to explain the origin of gases on the basis of the analytical
results of steam discharged from geothermal wells in the Matsukawa area.
Methods: chemical analyses (gas chromatography), H isotopes.
Results: The original deep seated gases of Northeast Japan are suggested
to be uniform with respect to He, Ar, N₂ and are emitted through geothermal
wells and/or fumaroles after mixing in various proportions with atmospheric
air dissolved in ground water. The correlation between gas components
indicates that the reaction, $2\text{NH}_3 = \text{N}_2 + 3\text{H}_2$, is in equilibrium, but the
reaction, $\text{CH}_4 + 2\text{H}_2\text{O} = \text{CO}_2 + 4\text{H}_2$, is not in equilibrium.

141 . A) Gen. Cat.--Hydrothermal systems.

B) Kennedy, B. M.; Lynch, M. A.; Reynolds, J. H.; Smith, S. P., 1985,
Intensive sampling of noble gases in fluids at Yellowstone: I.
Early overview of data, regional patterns: *Geochimica et Cosmo-*
chimica Acta, v. 49, no. 5, p. 1251-1261.

C) Purpose: discuss correlations in new data at Yellowstone.

Methods: mass spectrometry.

Results: isotopic variation in He and Ar can be explained by the mixing of 3 components: magmatic fluid, radiogenic ^4He , and atmospheric ^4He . Concentrations of ^{20}Ne remain difficult to account for. Xe and Ne show a strong inverse relationship. Yellowstone NP appears to be an integrated geothermal region with ^3He -rich plumes that are associated with a $^{40*}\text{Ar}$ component.

142. A) Gen. Cat.--Hydrothermal systems

- B) Polyak, B. G.; Prasolov, E. M.; Cermak, V.; Verkhouskiy, A. B.; 1985, Isotopic composition of noble gases in geothermal fluids of the Krušné Hory Mountains., Czechoslovakia, and the nature of the local geothermal anomaly: *Geochimica et Cosmochimica Acta*, v. 49, no. 3, p. 695-699.

- C) Purpose: detect sources of hydrothermal fluids at the study location.

Methods: mass spectrometry.

Results: heavy noble gases are in atmospheric proportions, indicating meteoric recharge. Excess He is attributed to radiogenic contributions. Data support a correlation between $^3\text{He}/^4\text{He}$ and heat flow. Local heat flow anomaly in this area is due to mass outflow, which occurred during the Alpine activation of the Bohemian massif.

143. A) Gen. Cat.--Active and semidormant hydrothermal systems

B) Smith, S. P.; Kennedy, B. M., 1985, Noble gas evidence for two fluids in the Baca (Valles Caldera) geothermal reservoir: *Geochimica et Cosmochimica Acta*, v. 219, no. 4, p. 893-902.

C) Purpose: examine fluid mixing using noble gases.

Methods: mass spectrometry.

Results: concentrations of $^{21}\text{Ne}^*$ and $^{40}\text{Ar}^*$ (normalized to ^4He) are nearly constant. $^3\text{He}/^4\text{He}$ ranges from 3.9 to 4.8 times atmospheric, indicating a mantle derived He component. Data indicate fluid mixing of 2 components; one is air-like but enriched in lighter gases and isotopes, the second is mantle derived and contains high concentrations of radiogenic and mantle derived gases.

1. A) Gen. Cat.--Igneous contact effects, hydrothermal

B) Shaw, D. M., 1960, The geochemistry of scapolite, Part II. Trace elements, petrology, and general geochemistry: Journal of Petrology, v. 1, p. 261-285.

C) Purpose: to determine trace element distribution, petrology and general geochemistry of scapolites.

Methods: chemical analysis of scapolite for trace and major elements.

Results: element concentrations in scapolites are related to formation regimes (hydrothermal environments as well as pyroxine hornfel facies).

2. A) Gen. Cat.--Igneous contact effects

B) Chinner, G. A., 1962, Almandine in thermal aureoles: Journal of Petrology, v. 3, p. 316-340.

C) Purpose: to explain the rarity of almandine in thermal aureoles.

Methods: chemical evaluation of garnets and other environmentally related minerals. Also evaluation of P/T stability fields of these minerals and equilibrium relations between them.

Results: Garnets are found to react with surrounding minerals during thermal metamorphism to hornfels and so become rare. The rarity is not caused by the P/T stability field of garnet being exceeded.

- 3 A) Gen. Cat.--Igneous contact effects
- B) Shaw, D. M.; Moxham, R. L.; Filby, R. H.; Lapkowsky, W. W., 1963, The petrology and geochemistry of some Grenville skarns: Canadian Mineralogist, v. 7, p. 420-442.
- C) Purpose: analysis of skarns from the Grenville province.
- Methods: chemical analysis of collected samples.
- Results: detailed analysis of the skarns is given. Among other contributory processes, intrusion of pegmatites is given as a mechanism for the skarn formation.

4. A) Gen. Cat.--Igneous contact effects.

B) Turner, F. J., 1965, Note on the genesis of brucite in contact metamorphism of dolomite: Contributions to Mineralogy and Petrology, v. 11, p. 393-397.

C) Purpose: to understand the formation of brucite under different conditions of contact metamorphism.

Methods: use of available thermodynamic data and published results of experiments.

Results: products of contact metamorphic change of dolomite are given under different partial pressures of CO₂ and water.

5 . A) Gen. Cat.--Igneous contact effects

B) Loomis, A. A., 1966, Contact metamorphic reactions and processes
in the Mt. Tallac roof remnant, Sierra Nevada, California:
Journal of Petrology, v. 7, p. 221-245.

C) Purpose: to determine reactions and their processes in contact
metamorphic facies.

Methods: petrography and chemical analysis plus hydrothermal laboratory
experiments.

Results: differences in facies are explained, mainly by differences in
water pressures and heat during formation.

6. A) Gen. Cat.--Igneous intrusive contact.

B) Boettcher, A. L.; Privinskii, A. J.; Knowles, C. R., 1967, Zoned potash feldspars from the rainy creek complex near Libby, Montana: Earth and Planetary Science Letters, v. 3, p. 8-10.

C) Purpose : to analyze zoned K-spars in a trachyte of the Rainy Creek Complex. A brief discription of contact with country rocks is given. The trachyte being a result of the contact of ultramafic rocks and country rock .

Methods : method of analysis of contact phenomena is not given, electron microprobe methods were used on the feldspar.

Results: limestones, dolomites and argillites surrounding the ultramafic complex are fenitized, yielding a product of syenitic composition enriched in K, Fe^{3+} , Ti and possibly other minor elements. A trachyte, formed in this way (which is at least in part rheomorphism or palingenesis of rest fenites), produced oscillatory zoned K-spars which are believed to have formed, not key variations in K, Ca, or Fe, since these elements are fairly constant across zoning. The celsian content however is variable and the zoning is attributed to it.

7. A) Gen. Cat.--Contact effects- intrusions

B) Jones, L. M.; Faure, G., 1967, Age of the Vanda porphyry dikes in Wright Valley, Southern Victoria Land, Antarctica: Earth and Planetary Science Letters, v. 3, p. 321-324.

C) Purpose: to describe geology of Wright Valley and date porphyry dikes in Wright Valley. Previous dating was ambiguous.

Methods: Rb-Sr dating methods.

Results : previous attempts at dating were ambiguous with field relations. A high initial $\text{Sr}^{87}/\text{Sr}^{86}$ ratio is assumed in this paper because of radiogenic Sr contamination, which was not considered previously. This contamination was determined to have occurred at time of emplacement by contamination by country rocks, rather than by later intrusions affecting the porphyry composition. An age was determined adjusting for ^{87}Sr contamination which is consistent with field relations.

8. A) Gen. Cat.--Intrusive contact effects

B) Davis, G. L.; et. al., 1968, Some effects of contact metamorphism on zircon ages: Earth and Planetary Science Letters, v. 5, p. 27-34.

C) Purpose: because of major difficulty in interpreting age discrepancies in zircons because their environmental history is little known, this study takes advantage of the thermal gradient in a contact aureole to test its influence on the isotopic lead ages of zircon and comparable effects on zircon with those on other minerals.

Methods: aureoles around two different Tertiary stocks in Colorado were studied. Samples were taken in the contact area on a traverse radiating out from the Stock. These samples were analyzed for the Pb, U, and Th content of their zircons.

Results: zircons show a progressive age decrease as the contact is approached - $^{206}\text{Pb}/^{238}\text{U}$ ages drop between 50' and 25' from the contact, from 1200 million years to 300 million years. $^{207}\text{Pb}/^{235}\text{U}$ patterns are similar. Lead decreases as the contact is approached while U and Th increase. The mechanism for this is speculated to be either a) episodic diffusion, b) recrystallization or c) crystallization. Since zircons became increasingly euhedral as contact was approached, b and c are favored models, although model a may play a part. It was noted in this paper that a previous study showed Rb-Sr ages of biotite and K-spar and K-Ar ages of biotite K-spar and hornblende showed about complete change from precambrian ages of country rock to Tertiary age as the contact was approached.

9 . A) Gen. Cat.—intrusions, contact effects

B) Kessler, S. E., 1968, Mechanisms of magmatic assimilation of a marble contact, northern Haiti: *Lithos*, v. 1, p. 219-229.

C) Purpose: to discuss the nature of assimilation products at carbonate contacts within a Tertiary quartz monzonite stock.

Methods: petrography, chemical analyses

Results: in the quartz monzonite stock, assimilation of the marble involved solution of solid marble and dispersal of material primarily by convection. Although the mechanism of addition by which the assimilation zones formed operated only at the surface of the marble, the assimilation zone attained unusual dimensions, which indicates that the development of extensive alteration zones in epizonal intrusions is controlled largely by the mechanism of assimilated material.

10. A) Gen. Cat.--Intrusions, temperature

B) Jennings, D. S.; Mitchell, R. H., 1969, An estimate of the temperature of intrusion of carbonatite at the Fen complex, S. Norway: *Lithos*, v. 2, p. 167-169.

C) Purpose: to provide an estimate of the temperature of the intrusions by means of the calcite-dolomite method of geothermometry.

Methods: XRD, calcite-dolomite geothermometry.

Results: the temperatures found (280-380°C) are in apparent agreement with theories which postulate the low temperature solid intrusion of carbonatite.

- 11 . A) Gen. Cat.--Igneous contact effects
- B) Cendrero, A., 1970, The volcano-plutonic complex of La Gomera (Canary Islands: Bulletin Volcanologique, v. 34, no. 2, p. 537-561.
- C) Purpose: to describe and analyze the volcano-plutonic complex of La Gomera in the Canary Islands.
- Methods: petrography and chemical analysis
- Results: a process of alkanization of the host rocks produced by the intrusion of syenitic rocks is described.

12 . A) Gen. Cat.--Igneous intrusive contact effects

B) Hanson, G. N.; Catanzaro, E. J.; Anderson, D. H., 1971, U-Pb ages for sphene in a contact metamorphic zone: Earth and Planetary Science Letters, v. 12, p. 231-237.

C) Purpose: U-Pb dates for sphene appear more reliable than U-Pb for zircon or K-Ar biotite + hornblende ages, however, U-Pb sphene dates are effected by thermal metamorphism. These effects are compared with similar effects to U-Pb zircon and K-Ar biotite and hornblende dates in a contact metamorphic zone (Grants Range Granite, Minn.).

Methods: samples were taken at varying distances from the granite complex and U-Pb dates for sphene were determined. A previous study's results of U-Pb zircon and K-Ar dating were used for the comparison.

Results: the U-Pb dates for sphene become more discordant as they approach the contact. These dates are found to be more reliable than the K-Ar dates but comparison with the U-Pb zircon dates is difficult to interpret because they are thought to have been discordant prior to or after the contact metamorphism.

13. A) Gen. Cat.—Igneous contact effects

B) Crawford, M. L., 1972, Plagioclase and other mineral equilibria in a contact metamorphic aureole: Contributions to Mineralogy and Petrology, v. 36, p. 293-314.

C) Purpose: analysis of mineral assemblages found in a contact aureole to determine equilibria.

Methods: minerals were analyzed by microprobe and x-ray diffraction. Conditions (temperature and pressure) of the contact were determined in a previous work.

Results: the minerals show some compositional changes with metamorphic grade as well as differences from one assemblage to another. No evidence of disequilibrium was found. Reactions between phases are discussed in relation to changes of mineral assemblages with increasing degree of metamorphism and changes of fluid composition.

14 . A) Gen. Cat.--Intrusive contact effects

B) Kamineni, D. C., 1974, Variation in the distortion index of cordierite east of the Sparrow Lake Granite Pluton, District of Mackenzie: Canadian Mineralogist, v. 12, p. 419-421.

C) Purpose: study of the contact effects on cordierite east of the Sparrow Lake Granite Pluton.

Methods: cordierite-bearing samples were collected at different distances from the pluton. The distortion index was determined from x-ray diffractograms.

Results: cordierite occurs in the metagreywacke and argillite that form a broad aureole about the pluton. The distortion index for the cordierite is found to be greatest farther away from the pluton and lessens as the pluton is approached.

15 . A) Gen. Cat.--Igneous contact effects

B) Simmons, E. C.; Lindsley, D. H.; Papike, J. J., 1974, Phase relations and crystallization sequence in a contact-metamorphosed rock from the Gunflint Iron Formation, Minnesota: *Journal of Petrology*, v. 15, p. 539-565.

C) Purpose: description of mineral assemblages and determination of their formation processes and environment during contact metamorphism.

Methods: petrographic, microprobe and x-ray diffraction.

Results: mineral assemblages are given for the metamorphosed zone, and original country rock is described. Environment of formation is determined and noted. Exsolution, inversion, oxidation and hydration reactions of minerals after recrystallization are described.

16. A) Gen. Cat.--Igneous contact effects

B) Springer, R. K., 1974, Contact metamorphosed ultramafic rocks in the Western Sierra Nevada foothills, California: Journal of Petrology, v. 15, p. 160-195.

C) Purpose: to describe and determine formation conditions of mineral assemblages in the contact zone of some ultramafic rocks.

Methods: petrography and comparison of mineral assemblages with experimental systems.

Results: zonation of mineral assemblages, as the contact is approached, is noted and temperature and pressure of formation is determined using experimental systems for comparison with observed assemblages.

17. A) Gen. Cat.--Igneous contact effects

B) Abraham, K.; Schreyer, W., 1975, Minerals of the viridine hornfels from Darmstadt, Germany: Contributions to Mineralogy and Petrology, v. 49, p. 1-20.

C) Purpose: analysis of mineral assemblages and composition changes in hornfels from Germany. Methods: petrography, microprobe, and chemical analysis. Results: mineral assemblages are given with compositions and discussion of fractionation of elements between phases. Equilibrium relations between phases is discussed.

18. A) Gen. Cat.--Igneous metamorphic effects

B) Arai, S., 1975, Contact metamorphosed dunite-harzburgite complex in the Chugoku District, western Japan: Contributions to Mineralogy and Petrology, v. 52, p. 1-16.

C) Purpose: investigation of contact effects to an ultramafic complex by two granitic intrusions.

Methods: microprobe of mineral assemblages, and wet chemical analysis.

Results: four zones based on mineral assemblages are established. Details of these assemblages are discussed and the zones are found consistent with experimental results in the system. $\text{MgO-SiO}_2\text{-H}_2\text{O}$. Formation pressure information is given.

19. A) Gen. Cat.--Igneous intrusive contact effects

B) Bunteborth, G., 1976, Distribution of uranium in intrusive bodies due to combined migration and diffusion: Earth and Planetary Science Letters , .v. 32, p. 84-90.

C) Purpose: to study the phenomenon of U and Th concentrations found on the central part of contact zones of igneous plutons and the wall rock.

Methods: using data on plutons of previous studies and applying a theoretical model to explain the effect.

Results: enrichment is believed to be caused by the migration of hydrous solutions which carry the element along intergranular paths toward the contact zone with the wall rock. The author proposes that the contact zone is a barrier at which the U is partly diffused away from the contact. The two particle flow, one toward the contact, one away from it, is described by a differential equation. Only a negligible amount of U enters the wall rock.

20. A) Gen. Cat.--Igneous contact effects

B) Kuniyoshi, S.; Liou, J. C., 1976, Contact metamorphism of the Karmutsen Volcanics, Vancouver Island, British Columbia: *Journal of Petrology*, v. 17, 73-99.

C) Purpose : analysis of igneous contact metamorphism of some volcanics.

Methods: petrographic and chemical analysis.

Results: the thermal effects are superimposed on prehnite-pumpellyite facies, former volcanics. The metamorphism is nearly isochemical except for H₂O. Considerable metasomatism is found in tuffs (chemical data is given). Two prograde zones are recognized and on the whole a low pressure condition is determined during contact metamorphism.

21. A) Gen. Cat.--Fenitisation

B) Rock, N.M.S., 1976, Fenitisation around the Monchique alkaline complex,
Portugal: Lithos, v. 9, no. 4, p. 263-279.

C) Purpose: to discuss the mineralogy and composition of the Monchique fenites,
and to compare these fenites to other areas.

Methods: petrography, electron microprobe, chemical analyses (XRF, wet chemistry)

Results: the principal element introduced during fenitisation was sodium,
together with minor iron and chlorine; potassic, oversaturated and strongly
peraluminous sediment compositions were thus transformed into nepheline-
bearing sodic rocks of foyactic aspect.

22 . A) Gen. Cat.--Igneous contact effects

B) Shieh, Y.; Schwarcy, H.; Shaw, D., 1976, An oxygen isotope study of the Loon Lake pluton and the Apsley gneiss, Ontario:

Contributions to Mineralogy and Petrology, v. 54, p. 1-16.

C) Purpose: study of oxygen isotope distribution in certain Grenville province rocks.

Methods: petrographic, chemical analysis.

Results: the $\delta^{18}\text{O}$ distribution does not change within the contact aureole as compared to the surrounding country rocks. Fractionation of ^{16}O and ^{18}O between minerals in the aureole is smaller than that found in the country rock.

23 . A) Gen. Cat.--Metasomatism

B) Brady, J. B., 1977, Metasomatic zones in metamorphic rocks: *Geochimica et Cosmochimica Acta*, v. 41, no. 1, p. 113-125.

C) Purpose: clarify consequences of diffusion in metamorphic rocks.

Methods: use of published data.

Results: modeling of metasomatic zones and rates of diffusion is only possible in simple systems, or if extensive thermochemical and kinetic data is available. The number of diffusing components can vary from zone to zone, and 'inert markers' are used to make comparisons. Observation of calc-silicate zones suggests that a diffusion-imposed gradient in the chemical potential of calcium is responsible for zonation. Other metasomatic zones may be produced by diffusion of more than one component.

- 24 . A) Gen. Cat.--Intrusive rocks, groundwater, geothermal systems
- B) Cathles, L. M., 1977, An analysis of the cooling of intrusives by ground-water convection which includes boiling: Economic Geology, v. 72, no. 5, p. 804-826.
- C) Purpose: to present results of model computations that bear on the relations between igneous intrusion, the formation of liquid and vapor dominated geothermal systems, and the formation of porphyry-type ore deposits.
- Methods: thermodynamic analyses.
- Results: a self-supported, vapor dominated steam zone is commonly (but briefly) formed above the intrusive. Condensed water bounds the steam zone above, and if the hydrothermal solutions are saline, a zone of boiling bounds the steam zone below. For pure water, condensation is far more important than boiling - the solutions circulate around the critical point of water to become gaseous without boiling.

25. A) Gen. Cat.--Meteoric water, intrusives

B) Tilling, R. I., 1977, Interaction of meteoric waters with magmas of the Boulder Batholith, Montana: *Economic Geology*, v. 72, no. 5, p. 859-864.

C) Purpose: to reexamine hydrogen and oxygen isotope data on unaltered Boulder batholith rocks in terms of the two-magma series model.

Methods: oxygen isotopes.

Results: results suggest that whether isotopic exchange is achieved by direct diffusion of water into a convecting magma body, by the stoping-assimilation-equilibration process, or by a combination of both, the ultimate source of the isotopically light oxygen is meteoric water.

26. A) Gen. Cat.--Igneous contact effects

B) Dodge, F. C. W.; Calk, L. C., 1978, Fusion of granodiorite by basalt, central Sierra Nevada: Journal of Research of the USGS, v. 6, no. 4, p. 459-465.

C) Purpose: analysis of contact effects between trachybasalt magma and porphyritic granodiorite.

Methods: petrography and major element analysis.

Results: an aureole in the granodiorite is about 3.5 m thick around the trachybasalt which is a plug 100 m in diameter. Changes in the normal mineralogy of the granodiorite is described in the aureole. Also the changes from the normal granodiorites major element chemistry is given and discussed.

27 . A) Gen. Cat.--Igneous intrusions

B) Gaál, G.; Isohanni, M., 1979, Characteristics of igneous intrusions and various wall rocks in some Precambrian porphyry copper-molybdenum deposits in Pohjanmaa, Finland: Economic Geology, v. 74, no. 5, p. 1198-1210.

C) Purpose: to describe three examples of porphyry-type mineralization from Pohjanmaa, Finland.

Methods: geologic mapping, petrography, geophysics, chemical analyses.

Results: four features characterize the porphyry-type mineralizations of Pohjanmaa: 1) they occur in epizonal intrusions which were emplaced in previously metamorphosed and deformed supracrustal rocks; 2) their intrusion contacts are sharp and without significant marks of contact metamorphism; 3) they seem to occur in the same stratigraphic setting, and they are all found in the same environment characterized by low to medium grade metamorphosed turbidites and intermediate pyroclastic rocks; and 4) they are located near or at the intersection of northeast- and northwest- striking faults.

28 . A) Gen. Cat.--Hydrothermal aureoles

B) Malpas, J., 1979, The dynamothermal aureole of the Bay of Islands ophiolite suite: Canadian Journal of Earth Sciences, v. 16, no. 11, p. 2086-2101.

C) Purpose: to describe an origin for the emplacement of the Bay of Islands ophiolite suite.

Methods: chemical analyses, petrography, thermodynamic analyses.

Results: the aureole was not produced simply by intrusion of hot masses of igneous rock, but is related directly to the emplacement of the thrust slices.

29 . A) Gen. Cat.--Igneous intrusions

B) Bennett, E. H., 1980, Granitic rocks of Tertiary age in the Idaho Batholith and their relation to mineralization: *Economic Geology*, v. 75, no. 2, p. 278-888.

C) Purpose: to describe the characteristics of Tertiary granitic plutons in the Idaho batholith and to relate them to mineralization.

Methods: Gamma ray spectroscopy, literature review, oxygen and hydrogen isotopes.

Results: 42 plutons of Tertiary age have been identified. They are characterized by a high background radioactivity relative to the Cretaceous batholith, a distinctive topographic expression, and the presence of miarolitic cavities containing well-formed smoky quartz crystals and other minerals.

30 . A) Gen. Cat.--Igneous intrusions .

B) Sata, K., 1980, Tungsten skarn deposit of the Fujigatani Mine, south-west Japan: Economic Geology, v. 75, no. 7, p. 1066-1082.

C) Purpose: to describe the mode of occurrence and mineral assemblages of the ore, and to provide chemical data for the principal constituent minerals.

Methods: petrography, chemical analyses.

Results: the Fujigatani and nearby tungsten deposits were formed in relation to the ilmenite series granitic rocks of upper Cretaceous age.

31 . A) Gen. Cat.-- Igneous intrusions

B) Naeser, C. W.; Cunningham, C. G.; Marvin, R. F.; Obradovich, J. D.,
1980, Pliocene intrusive rocks and mineralization near Rico,
Colorado: Economic Geology, v. 75, no. 1, p. 122-133.

C) Purpose: to show evidence for a major heat source that cooled in
late Miocene or early Pliocene and is centered under the mineralized
rocks near the townsite of Rico.

Methods: K-Ar dating, fission track dating.

Results: coincidence in time and space between the young mineralization,
young intrusive rocks, and hidden thermal center east of Rico suggests
that this may be the site for a young, unexposed stock with the
potential for porphyry type mineralization.

32. A) Gen. Cat.--Igneous contact effects

B) Viladkar, S. G., 1980, The fenitized aureole of the Newania carbonatite,
Rajasthan: Geological Magazine, v. 117, p. 285-295.

C) Purpose: description of the Newania carbonatite and surrounding aureole.

Methods: chemical analysis (major elements) and petrography.

Results: chemical analysis and petrography of the carbonatite and its aureole are given. The aureole is a zone of fenitization of granite gneiss country rock that has been converted into syenitic fenite.

33 . A) Gen. Cat.--Igneous intrusions

B) Nokleberg, W. J., 1981, Geologic setting, petrology, and geochemistry of zoned tungsten-bearing skarns at the Strawberry Mine, Central Sierra Nevada, California: Economic Geology, v. 76, no. 1, p. 111-133.

C) Purpose: to present detailed data on the geologic setting, petrology, and geochemistry of the Strawberry mine tungsten-bearing skarns, as well as a model of skarn zonation dominated by infiltration metasomatism.

Methods: field mapping, mine mapping, petrography, electron microprobe.

Results: skarn formed when an aqueous fluid, relatively enriched in Si, Fe, Mg, Mn, Al, Na, K, and W and relatively depleted in Ca and CO₂, was expelled from the granodiorite of Strawberry mine into overlying wall rocks containing nearly subvertical layers of calcite-rich marble.

34 . A) Gen. Cat.--contact aureoles

B) Bacher-Nurminen, K., 1982, On the mechanism of contact aureole formation in dolomitic country rock by the Adamello intrusion (northern Italy): *American Mineralogist*, v. 67, no. 11 and 12, p. 1101-1117.

C) Purpose: to describe a contact aureole in dolomitic country rocks from the southern Alps.

Methods: petrography, electron microprobe.

Results: the observed mineralogical zoning of the aureole is the result of silica- and aluminum metasomatism.

35. A) Gen. Cat.--Igneous intrusions, contact effects

B) Kissin, S. A.; Turner, G. W., 1982, A pseudotactite assemblage in the footwall of a massive sulfide occurrence, Savant Lake-Sturgeon Lake Greenstone Terrains, Ontario: Canadian Journal of Earth Sciences, v. 19, no. 8, p. 1691-1696.

C) Purpose: to present a description of a skarn-like assemblage in the Hadley occurrence, a small massive sulfide body in the western Superior Province, and an interpretation of the conditions under which it formed.
Methods: thermodynamic analyses, electron microprobe.
Results: temperatures, fluid pressures, and X_{CO_2} estimated on the basis of silicate phase equilibria suggest that an H_2O -rich fluid at pressures greater than 2 kbar (200 MPa) coexisted with the rocks of the Hadley occurrence. The minimum temperature was $460^{\circ}C$, also on the basis of aluminosilicate phase equilibria.

36. A) Gen. Cat.--Igneous contact effects

B) Nogy, K. L.; Parmentier, E. N., 1982, Oxygen isotopic exchange at an igneous intrusive contact: Earth and Planetary Science Letters, v. 59, p. 1-10.

C) Purpose: to study the effects of O isotope exchange at a contact zone.

Methods: collected samples were analyzed for O isotope values.

Results: $\delta^{18}\text{O}$ exchange has taken place at the contact zone of an igneous intrusion in the Santa Rosa Range, Nevada. Exchange may have taken place solely by diffusion or possibly partly by fluid flow across the contact. Several mechanisms of diffusion are examined.

37. A) Gen. Cat.--Metasomatism, alkali or Aureoles, metasomatic
- B) Rubie, D. C., 1982, Mass transfer and volume change during alkali metasomatism at Kisingiri, Western Kenya: Lithos, v. 15, no. 2, p. 99-109.
- C) Purpose: to investigate processes of mass transfer and volume change during alkali metasomatism at Kisingiri.

Methods: chemical analyses (XRF, wet chemistry)

Results: the model developed suggests volume decreases of up to 20% in a zone adjacent to the intrusions and approximately constant volume beyond this zone. Such volume decreases are explained by the removal of quartz by dissolution and diffusion into the crystallizing magma. Aluminum was almost immobile according to this model.

38. A) Gen. Cat.--Igneous contact effects

B) Sabine, P. A.; Beckinsale, R. D.; Evans, J. A.; Walsh, J. N., 1982, Geochemical and strontium-isotope studies of reactions between basic magma, chalk, and flint, and the role of groundwater, in the carneal plug, Co. Antrim, Northern Ireland: *Journal of Petrology*, v. 23, p. 427-446.

C) Purpose: to analyze an occurrence of basic magma contacting chalk and flint.

Methods: petrography, mineralogy, and chemical analysis (major, trace and Sr isotope)

Results: description of mineral suites is given and discussed. Major, trace elements and Sr isotope data is also given and discussed.

39. A) Gen. Cat.--Major intrusion, contact effects

B) Dallmeyer, R. D.; Kean, B. F.; Odom, A. L., and Jayasinghe, N. R.,
1983, Age and contact metamorphic effects of the Overflow Pond
Granite: an undeformed pluton in the Dunnage Zone of the Newfound-
land Appalachians: Canadian Journal of Earth Sciences, v. 20,
p. 1639-1645.

C) Purpose: to undertake an integrated U-Pb and $^{40}\text{Ar}/^{39}\text{Ar}$ geochronological
investigation of a portion of the Dunnage zone in order to better
constrain the age of late plutonic activity.

Methods: U-Pb zircon analyses, $^{40}\text{Ar}/^{39}\text{Ar}$ biotite analyses, petrography.

Results: the textural and geochronological results discussed suggest
that at around 390 Ma the Overflow Pond Granite intruded a deformed,
low grade metasedimentary succession at relatively shallow crustal
levels with the resultant development of a significant contact aureole.

40. A) Gen. Cat.--Igneous intrusions, uraniferous
- B) Fowler, A. D.; Doig, R., 1983, The age and origin of Grenville Province uraniferous granites and pegmatites: Canadian Journal of Earth Sciences, v. 20, no. 1, p. 92-104.
- C) Purpose: to test the hypothesis that the uranium-mineralized granites and pegmatites of the Grenville province formed by anatexis of a uranium-enriched sedimentary protolith.
- Methods: Rb-Sr isotopic methods, petrography.
- Results: initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios range from .7028 to .7054, plus one poorly defined value of .709. Excluding this last one, these values are only slightly greater than mantle ratios, and calculations show that these rocks could not have been derived from the quartzofeldspathic gneisses of these areas. The authors suggest an origin by deep melting due to isothermal decompression during rapid uplift as an alternative explanation.

41. A) Gen. Cat.--Diagenesis or Contact metamorphism

B) Kastner, M.; Siever, R., 1983, Siliceous sediments of the Guaymas Basin:

The effect of high thermal gradients on diagenesis: Journal of Geology, v. 91, no. 6, p. 629-641.

C) Purpose: evaluate the course of diagenesis of siliceous and turbiditic sediments.Methods: petrography, mass spectrometry, SEM, XRD, wet chemical methods.

Results: conversion of siliceous sediment to opal-CT and quartz took only thousands or tens of thousands of years to complete because of high geothermal gradients, and in particular due to proximity to igneous intrusions. Convective cells operate above the sills. Thermally-induced phase changes below the sills were restricted to the immediate vicinity of the contacts. Near the contacts, opal-A dissolves and recrystallizes as quartz or is lost by being carried away in solution by convection. Opal-CT forms only when Si-rich solutions could not escape along fractures or was not carried away by convection.

42 . A) Gen. Cat.--Igneous intrusions

B) Kerans, C., 1983, Timing of emplacement of the Muskox intrusion:

constraints from Coppermine homocline cover strata: Canadian Journal of Earth Sciences, v. 20, no. 5, p. 673-683.

C) Purpose: to clarify the age relationships of the intrusion relative to the Dismal Lakes and Coppermine River Groups, a relationship that has not been satisfactorily established since the discovery of the intrusion.

Methods: Geologic mapping, review of literature.

Results: support earlier contentions that the Mackenzie igneous event, comprising emplacement of Mackenzie dikes, Coppermine River group basalts, and the Muskox intrusion, was a coherent igneous event that occurred approximately 1200 Ma ago, with the Muskox intrusion as a locus.

43 . A) Gen. Cat.--Major plutons, contact effects

B) Cawthorn, R. G.; Barton, J. M., Jr.; Viljoen, M. J., 1985, Interaction of floor rocks with the Platreef on Overysel, Potgietersrus, northern Transvaal: *Economic Geology*, v. 80, June-July, p. 988-1006.

C) Purpose: to describe the interaction of floor rocks with the Platreef at Overysel.

Methods: petrography, chemical analyses (XRF), Rb, Sr isotopes.

Results: the feldspathic pyroxenite of the Platreef appears to be highly contaminated as it has high concentrations of K_2O , Rb, and Ba and a high and variable $^{87}Sr/^{86}Sr$ ratio, calculated at the time of intrusion, of .7104 to .7277. All of the floor rocks have been geochemically investigated to determine if any were the source of this contamination. Geochemical evidence suggests that granite in the floor rocks has contaminated the Platreef.

44 . A) Gen. Cat.—Igneous intrusions

B) James, L. P.; McKee, E. H., 1985, Silverhead-zinc ores related to possible Laramide plutonism near Alta, Salt Lake County, Utah: Economic Geology, v. 80, no. 2, p. 497-504.

C) Purpose: to show evidence for Laramide plutonism in the region.

Methods: K-Ar dating, chemical analyses, petrography, and geophysical methods.

Results: Radiometric ages indicate a period of Late Cretaceous (Laramide) dioritic intrusion and a younger period of Oligocene dacitic and granodiorite intrusion in the Argenta area.

METAMICTIZATION

1 . A) Gen. Cat.--Metamictization

B) Akhmanova, M. V.; Leonova, L. L., 1961, Investigation of metamictization of zircons with the aid of infrared absorption spectra: *Geochemistry*, no. 5, p. 416-431.

C) Purpose: examine mechanisms of metamictization in zircon.

Methods: infrared absorption spectra

Results: metamictization of zircon is caused by deformation of SiO_4 tetrahedra. The amount of deformed tetrahedra is proportional to U-content in the range 1×10^{-3} to 1%. Complete metamictization is induced by 1% U. No dissociation of zircons into oxides was observed. Heating can restore deformed tetrahedra.

2. A) Gen. Cat.--Metamictization

B) Karyakin, A. V., 1962, Mechanism of liberation of helium from metamict zircons: *Geochemistry*, no. 8, p. 764-768.

C) Purpose: examine negative and positive vacancies in zircon.

Methods: electron paramagnetic resonance, infrared absorption spectra.

Results: the presence of F (negative) and V(positive) centers has been established. These centers are produced by irradiation and destroyed by the production of helium. Neutral He atoms are produced when positively charged He ions in v-centers are neutralized by the trapped electrons in F-centers.

3 . A) Gen. Cat.--Metamictization

B) Lipova, I. M.; Kuznetsova, G. A.; Makarov, Y. S., 1965, An investigation of the metamict state in zircons and cyrtolites: *Geochemistry International*, v. 2, no. 3, p. 513-525.

C) Purpose: gain a better understanding of the mechanism of metamictization.

Methods: XRF, luminescence, photometry.

Results: metamictization is related to high contents of U and Th as well as Hf, REE and H₂O. Alpha recoil nuclei can fuse the crystal and displace atoms. Data indicate that metamictization is a complex process involving changes in the lattice but not in composition. The mineral breaks down into its oxide components ($ZrSiO_4 \rightarrow ZrO_2 + SiO_2$).

4. A) Gen. Cat.--Metamictization

B) Pyatenko, Y. A., 1970, Behavior of metamict minerals on heating and the general problem of metamictization: *Geochemistry International*, v. 8, no. 5, p. 758-763.

C) Purpose: show that the effects of heating are important to understanding metamictization.

Methods: literature review.

Results: metamict minerals may be regarded as products of a specific unmixing of a solution. Local charge surpluses and deficiencies, in violation of Pauling's second rule, is a characteristic feature of many metamict minerals. The free energy of a metamict mineral is less than that of the mineral containing only crystal defects (at low temperatures). The radioactive hypothesis of metamictization may be only one factor in this process.

5 . A) Gen. Cat.--Metamictization

B) Krivokoneva, G. K.; Sidorenko, G. A., 1971, The essence of the metamict transformation in pyrochlores: *Geochemistry International*, v. 8, no. 1, p. 113-122.

C) Purpose: quantitatively evaluate structural changes during metamictization.

Methods: XRD, IR spectra.

Results: the mechanism of metamictization in pyrochlores involves deformation and size reduction of coherent-scattering blocks as lattice atoms and are displaced by alpha particles. The eventual result is a vitreous state. Recrystallization can occur by growth in coherent-scattering blocks or fragments of undamaged lattice. Differential thermal analysis is unsuitable for determining the degree of metamictness, while analysis of diffraction lines can provide quantitative data.

6 . A) Gen. Cat.--Metamictization

B) Moiseyev, B. M.; Portnov, A. M.; Fedorov, L. I., 1971, Nuclear magnetic resonance of ^{19}F in metamict minerals: *Geochemistry International*, v. 8, no. 3, p. 456-457.

C) Purpose: estimate lattice destruction due to metamictization.

Methods: nuclear magnetic resonance

Results: the ^{19}F NMR spectra were identical for the crystalline and metamict states of britholite and melanocerite. Short range order is retained around the ^{19}F in both cases. However, microcrystallites are disoriented in the metamict state.

7 . A) Gen. Cat.—Metamictization

B) Krasnobayev, A. A.; Polezhayev, Y. M.; Yunikov, B. A.; Novoselov, B. K.,
1974, Laboratory evidence on radiation and the genetic nature of
the metamict zircon: *Geochemistry International*, v. 11, no. 1,
p. 195-209.

C) Purpose: attempt to quantify Q (metamictness) in zircons.

Methods: alpha-counting, mass spectrometry, X-ray analyses, differential
thermal analysis, IR examination.

Results: the degree of metamictness is a function of both alpha-ray
dose and details of the minerals composition and structure (a genetic
factor). The genetic factor can result in an unstable state that
accentuates the effects of alpha radiation. Complete metamictization
of a zircon during the time of the earth's existence is only possible
if genetic imperfection contributes to it.

8. A) Gen. Cat.--Metamictization

B) Polezhayev, Y. M., 1974, On mechanism of metamictization of minerals under the action of autoradiation: *Geochemistry International*, v. 11, no. 6, p. 1157-1161.

C) Purpose: examine the effects of autoradiation during metamictization.

Methods: none discussed ("analyzed chemically")

Results: metamictization, when induced by autoradiation, bypasses the liquid state. Structural deformation is caused by local heating, expansion of an incompressible solid, and an abrupt increase in pressure. Deformation of the crystal structure is the first step in metamictization.

1 . A) Gen. Cat.--Mineral solubilities

B) Morey, G. W.; Fournier, R. O.; Rowe, J. J., 1962, The solubility of quartz in water in the temperature interval from 25°C to 300°C: *Geochimica et Cosmochimica Acta*, v. 26, no. 10, p. 1029-1043.

C) Purpose: expand solubility data on quartz.

Methods: wet chemical analyses.

Results: quartz-solution equilibrium is reached within a few days at 100°C. At room temperature, silica in solution reached 395ppm after 370 days, and then dropped to 6ppm due to quartz precipitation. Quartz solubility increases directly with temperature, in both rate and amount.

2. A) Gen. Cat.--Mineral solubilities

B) Weill, D. F.; Fyfe, W. S., 1964, The solubility of quartz in H₂O in the range 1000-4000 bars and 400-550°C: *Geochimica et Cosmochimica Acta*, v. 28, no. 8, p. 1243-1255.

C) Purpose: obtain further solubility data for quartz.

Methods: crystal weight loss method.

Results: rate of quartz solution in H₂O can be given by:

$dx/dt = a - bx$, where x is concentration of SiO₂ in solution at time t .

a and b are temperature dependent constants. Thermodynamic calculations indicate the accepted solution reaction (SiO₂ + 2H₂O \rightleftharpoons Si(OH)₄) does not account for solute behavior. This may be due to variations in the solution mechanism with temperature.

3 . A) Gen. Cat.--Mineral solubilities or Hydrothermal systems

B) Lagache, M., 1976, New data on the kinetics of the dissolution of alkali feldspars at 200°C in CO₂ charged water: Geochimica et Cosmochimica Acta, v. 40, no. 2, p. 157-161.

C) Purpose: supplements previous data on feldspar dissolution.

Methods: XRD, flame photometry, colorimetry.

Results: dissolution rates of Na⁺ and K⁺ are smooth continuous functions of the product of surface area "s" and time "t" (st), implying control by solution composition. Perthite (Na_{.45}K_{.55}Si₃O₈) dissolved as if composed of albite and k-spar grains. These results do not support diffusional mass transfer as a mechanism.

4. A) Gen. Cat.--Mineral solubilities

B) Marshall, W. L., 1980, Amorphous silica solubilities - I. Behavior in aqueous sodium nitrate solutions; 25 - 300°C, 0-6 molal: *Geochimica et Cosmochimica Acta*, v. 44, no. 7, p. 907-913.

C) Purpose: determine the effect of a 1:1 electrolyte on amorphous silica solubility.

Methods: colorimetry, spectrophotometry.

Results: a 60% decrease in silica solubility, relative to water, was recorded in the 6.12 m sodium nitrate solution at 25°C; a 27% decrease was recorded at 300°C. Molal heat of solution, in 6 m Na₂NO₃, increases from +2.93 kcal/mol at 100°C to +3.64 kcal/mol at 300°C. As Na₂NO₃ approaches saturation (10.8 m), the molal heat of solution approaches a constant +3.8 kcal/mol.

5 . A) Gen. Cat.--Mineral solubilities

B) Marshall, W. L.; Warakomski, J. M., 1980, Amorphous silica solubilities - II.

Effect of aqueous salt solutions at 25°C: *Geochimica et Cosmochimica Acta*, v. 44, no. 7, p. 915-924.

C) Purpose: obtain solubilities in various salt solutions and compare to results for Na_2NO_3 solution.

Methods: colorimetry, spectrophotometry.

Results: for all ten salts studied, the solubility of silica decreased from its value in pure water. However, the amount of decrease varied, from 6% in saturated NaHCO_3 solution, to a 95.7% decrease in saturated CaCl_2 solution. At any given molality, effects on silica solubility depended on the cation in the order Mg^{2+} , $\text{Ca}^{2+} > \text{Li}^+ > \text{Na}^+ > \text{K}^+$.

6 . A) Gen. Cat.--Mineral solubilities

B) Marshall, W. L., 1980, Amorphous silica solubilities - III. Activity coefficient relations and predictions of solubility behavior in salt solutions, 0 - 350°C: *Geochimica et Cosmochimica Acta*, v. 44, no. 7, p. 925-931.

C) Purpose: search for further correlations between solubility of silica and salt solutions.

Methods: calculations based on data published in previous 2 articles.

Results: logs of activity coefficients yield straight lines when plotted against molarity of added salt, even to 6M. The same plots in terms of molality, instead of molarity, produced lines that became curves at higher molalities. It appears that amorphous silica is fully hydrated and in equilibrium with solution at 25°C. The general straight line relationship might be used to predict silica solubilities at high temperatures in solutions of other salts.

7 . A) Gen. Cat.--Mineral solubilities

B) Willey, J. D., 1980, Effects of aging on silica solubility: a laboratory study: *Geochimica et Cosmochimica Acta*, v. 44, no. 4, p. 573-578.

C) Purpose: investigate changes in surface area and solubility in silica over time.

Methods: AAS, XRD.

Results: solubility of silica decreased by approximately 20% after being in contact with seawater or NaCl solution for several months. Surface area decreases by about $\frac{1}{2}$ during the same interval. These decreases may be caused by the formation of a surface layer that is denser than the original surface.

8 . A) Gen. Cat.--Mineral solubility

B) Chen, C. A.; Marshall, W. L., 1982, Amorphous silica solubilities IV.

Behavior in pure water and aqueous sodium chloride, sodium sulfate, magnesium chloride, and magnesium sulfate solutions up to 350°C:

Geochemica et Cosmochimica Acta, v. 46, no. 2, p. 279-287.

C) Purpose: extend present data on silica solubility to higher temperatures.

Methods: XRD, spectrophotometry.

Results: silica solubilities were most depressed by $MgCl_2$, followed by $MgSO_4$ and $NaCl$. At higher temperatures, the effects of the salts were diminished, with the exception of Na_2SO_4 , which increased solubility with increasing T. This data allows prediction of amorphous silica solubility in single salt solutions.

9. A) Gen. Cat.—Mineral solubilities.

B) Marshall, W. L.; Chen, C. A., 1982, Amorphous silica solubilities V.

Predictions of solubility behavior in aqueous mixed electrolyte solutions to 300°C: *Geochimica et Cosmochimica Acta*, v. 46, no. 2, p. 289-291.

C) Purpose: show that silica solubilities in multiple salt solutions can be predicted from solubilities in single salt solutions.

Methods: XRD, spectrophotometry.

Results: to a first approximation, proportionality constants "D" (related to salt type and temperature) are additive for various salts at the same temperature. Silica solubilities fit the Setchenow equation:

$$\log (s^0/s) = \sum_i D_i m_i$$

where s^0 and s are silica solubilities in pure water and salt solution, respectively, and m is the molality of the salt. Calculated and experimental results agree reasonably well.

10.A) Gen. Cat.--Mineral solubilities

B) Marshall, W. L.; Chen, C. A., 1982, Amorphous silica solubilities - VI.

Postulated sulfate - silicic acid solution complex: *Geochemica et Cosmochimica Acta*, v. 46, no. 3, p. 367-370.

C) Purpose: present a quantitative relation to describe silica solubilities in Na_2SO_4 solutions.

Methods: calculations based on published data.

Results: are inconclusive. A solution complex of $\text{Si}(\text{OH})_4 \cdot \text{SO}_4^{2-}$ is postulated to account for salting-in of aqueous silica by Na_2SO_4 at high temperatures. This is suggested by observations of the salting-in effect and calculated association constants that show a van't Hoff relation.

11. A) Gen. Cat.--Mineral solubilities

B) Eyal, Y.; Fleischer, R. L., 1985, Preferential leaching and the age of radiation damage from alpha decay of minerals: *Geochimica et Cosmochimica Acta*, v. 49, no. 5, p. 1155-1164.

C) Purpose: consider effects of leaching on loss of actinides from mineral phases.

Methods: alpha spectrometry, XRD, SEM, EMP, SIMS, nuclear track technique.

Results: release of radionuclides into solution due to alpha decay contributes to isotopic disequilibrium. Spontaneous annealing of this radiation damage can diminish leaching effects in thorianite and uraninite. Leaching of ^{228}Th is strongly enhanced relative to ^{232}Th ; leaching of ^{234}U and ^{230}Th relative to ^{238}U and ^{232}Th is only slightly enhanced.

MINOR INTRUSIONS, CONTACT EFFECTS

1 . A) Gen. Cat.--Minor intrusions, contact effects

B) Mukherjee, B., 1965, Petrological and electrical conductivity characters of coals, affected by igneous intrusives around Pathardih, in Jharia Coalfield, Dhanbad district, India: Economic Geology, v. 60, no. 7, p. 1451-1458.

C) Purpose: to study the petrologic and electrical conductivity characters of coals affected by igneous intrusions in the Dhanbad district in India.

Methods: petrography, chemical analyses (unspecified), reflectance studies, electrical conductivity studies

Results: electrical conductivity measurements of these samples show that seams intruded by a sill show maximum conductivity with the "most affected coal," nearest to the intrusive, whereas in the case of seams intruded by a dike, the maximum conductivity is found with "partially affected coal," at some distance from the contact with the intrusive. The "unaffected coal" shows minimum conductivity in each case. The intrusions have rendered a large quantity of coal completely worthless to mine.

2 . A) Gen. Cat.--Minor intrusions, contact effects

B) Kisch, H. J.; Taylor, G. H., 1966, Metamorphism and alteration near an intrusive-coal contact: Economic Geology, v. 61, no. 2, p. 343-361.

C) Purpose: to describe the effects of a porphyritic hypabyssal intrusion on a coal seam.

Methods: petrography, XRD, reflectance studies

Results: the coal was affected up to 2.5 feet below the lower contact.

Near the contacts the coal had been converted to a natural coke with fine coke mosaic structure and inertinite-rich band. From reflectances and other considerations, it is concluded that temperatures attained during the metamorphism did not exceed 760°C.

3 . A) Gen. Cat.--Minor intrusions, contact effects

B) Kisch, H. J., 1966, Carbonitization of semi-anthracitic vitrinite by an analcime basanite sill: Economic Geology, v. 61, no. 6, p. 1043-1063.

C) Purpose: to discuss the effects of intrusion by an analcime basanite sill on a seam of semi-anthracitic coal.

Methods: petrography, proximate analyses, chemical analyses, reflectance studies.

Results: the intrusion of the sill below the coal seam changed the semi-anthracite to anthracite, meta-anthracite, and vesicular-natural coke. Marginal alteration of the intrusive by the volatiles evolved mainly affected the ferromagnesian silicates, and was relatively slight.

4 . A) Gen. Cat.--Minor intrusions, contact effects

B) Ghosh, T. K., 1967, A study of temperature conditions at igneous contacts with certain Permian coals of India: Economic Geology, v. 62, no. 1, p. 109-117.

C) Purpose: to investigate the temperature conditions at the igneous contacts of seven coal seams.

Methods: petrography, chemical analyses (unspecified), reflectance studies.

Results: the pressure effect of the intrusive during the thermal metamorphism was negligible and the maximum temperature to which the coal seams were subjected was about 600°C. Proximate composition, ultimate composition (carbon and hydrogen contents) and reflectance show a sharp change near the intrusive contact.

5. A) Gen. Cat.--Minor intrusions, contact effects

B) Graham, R. A. F., 1968, Effects of diabase dike intrusion on sulfide minerals at Manitouwadge, Ontario: Canadian Journal of Earth Sciences, v. 5, (June, part 1), p. 545-547.

C) Purpose: to study the sulfide minerals in the contact zone of this dike to determine the effects of high temperature thermal metamorphism on sulfide minerals.

Methods: petrography, XRD, electron microprobe

Results: it is suggested that intrusion of the diabase dike at Willroy caused copper and sulfur in the country rock to move towards the dike. Copper may have moved by a process of solid diffusion, possible grain boundary diffusion, and sulfur may have moved as a vapor. Both were prevented from entering the dike by the glassy chilled margin.

6 . A) Gen. Cat.--Evaporites, minor intrusions

B) Holwerda, J. G.; Hutchinson, R. W., 1968, Potash-bearing evaporites in the Danakil area, Ethiopia: *Economic Geology*, v. 63, no. 2, p. 124-150.

C) Purpose: to describe the evaporites, the sylvanite deposit, and their numerous unique geologic features to outline the processes of their formation and to discuss their comparison with natural and theoretical evaporite successions.

Methods: geologic mapping, chemical analyses (wet chemistry), XRD.

Results: this evaporite sequence lacks a basal zone of K- and Ca-free magnesium sulfates, probably due to non-deposition, but unlike most others, it has a distinctive, primary kainite zone. Temperatures during evaporite deposition ranged from 25 to 55 degrees C. Sylvite, formed by selective leaching of $MgCl_2$ from carnallite, is of secondary origin.

It is important to note that basic intrusions have invaded this sequence.

7. A) Gen. Cat.--Minor igneous intrusions, contact effects

B) Chakrabarti, A. K., 1969, On the effects of igneous intrusion on a few coal seams of the Jharia coal field, Bihar, India:
Economic Geology, v. 64, no. 3, p. 319-324.

C) Purpose: to discuss the effects of igneous intrusions on coal seams.

Methods: petrography, microphotometry, chemical analyses (unspecified), electrical conductivity tests.

Results: the effect of an igneous intrusion on a coal seam has a distinct bearing on the increase in rank of coal, which is obvious from the results of proximate and statistical maceral analyses.

It is observed from proximate analysis that the ash percentage decreases away from the contact of the seam and the intrusive body, whereas the volatile matter increases in the same direction.

8 . A) Gen. Cat.--Minor intrusions, contact effects

B) Irvine, T. N., 1970, Heat transfer during solidification of layered intrusions,

I. Sheets and sills: Canadian Journal of Earth Sciences, v. 7 (Aug.)

p. 1031-1061.

C) Purpose: to examine the various factors that may influence solidification rates and contact effects of intrusions in which the settled crystals were fractionated as they formed from the magma.

Methods: thermodynamic analyses.

Results: several points of general significance can be summarized as follows:

1) crystal settling acts to shorten the time required for an intrusion to solidify. 2) contact effects should be more pronounced around the upper reaches of a layered intrusion and less pronounced around the lower reaches than if the settled crystals had frozed to the roof. 3) heat loss downward through the floor of a layered intrusion generally will not be rapid enough to cause extensive amounts of adcumulus growth.

9 . A) Gen. Cat.--Dike contacts

B) Mookherjee, A.; Dutta, N. K., 1970, Evidence of incipient melting of sulfides along a dike contact, Geco Mine, Manitouwadge, Ontario: Economic Geology, v. 65, no. 6, p. 706-713.

C) Purpose: to describe the sulfide liquation along a diabase dike at the Geco mine.

Methods: petrography, thermodynamic analyses.

Results: if the Geco occurrence can be taken as a small scale model to evaluate the role of heat in ore remobilization, the following conclusions seem rational: a) partial melting of pre-existing sulfides can and does occur in response to thermal treatment; b) the extensive sulfide liquid field in the Cu-Fe-S system possibly splits up into three parts with the introduction of Zn in the system. The third liquid field above the $Cp_{SS}-Po_{SS}$ join should form below $860^{\circ}C$; c) such molten product can account for minor redistribution of metals within or close to the existing ore body, but is perhaps inadequate for "regenerating" entirely new ones.

10. A) Gen. Cat.--Dikes, coal

B) Podwysocki, M. H.; Dutcher, R. R., 1971, Coal dikes that intrude lamprophyre sills: Purgatoire River Valley, Colorado: Economic Geology, v. 66, no. 2, p. 267-280.

C) Purpose: to examine the relationships of the coal dikes and the lamprophyres and, by means of chemical and petrographic data and field observations, to determine the mode of emplacement and mobilization temperature for this unusual occurrence of coal.

Methods: petrography, chemical analyses, XRD.

Results: it is concluded that the coal was emplaced while in a fluid or at least plastic state, this fluidity being caused by heat from the adjacent lamprophyric sills. Petrographic study indicates that in all samples, the original reactive components have been altered to a homogeneous mass of non-mosaic to coarse mosaic material, indicators of thermal metamorphism. The non-mosaic material indicates a temperature of 427-463°C and the fine to coarse mosaic material gives evidence for 522° to 563°C temperatures.

11. A) Gen. Cat.--Dikes

B) Dickey, J. S., Jr.; Obata, M., 1974, Graphitic hornfels dikes in the Rhonda high-temperature peridotite massif: *American Mineralogist*, v. 59, no. 11 and 12, p. 1183-1189.

C) Purpose: to describe a group of graphite- and cordierite-rich dikes which apparently originated by intrusion and metamorphism of hydrocarbon-charged mud during the final emplacement of the peridotite massif.

Methods: petrography, electron microprobe, carbon isotopes.

Results: the hornfels dikes are believed to be metamorphosed, organic-rich muds which entered fractures in the hot, solid peridotite body as it was emplaced into or onto crustal sediments. Fe-Mg distribution between coexisting cordierite, garnet, and biotite in two dike specimens suggests equilibration at approximately 800°C.

12 . A) Gen. Cat.--Igneous contacts, minor intrusions

B) Fratta, M.; Shaw, D. M., 1974, 'Residence' contamination of K, Rb, Li, and Tl in diabase dikes: Canadian Journal of Earth Sciences, v. 11, no. 3, p. 422-429.

C) Purpose: to compare element abundances obtained from a single dike which cuts granitic rocks at one locality and basic rocks at another.

Methods: chemical analyses (standard rapid methods, AA)

Results: The portion of the dike intruding the granite has statistically significant higher contents of K, Rb, Li, and Tl, as a result of in situ, residence, contamination from country rock. Ion transfer from the granite toward the diabase took place mainly before the magma crystallized, therefore a process of differentiation was superimposed to that of diffusion.

13. A) Gen. Cat.--Minor intrusions

B) Dypvik, H., 1979, Major and minor element chemistry of Triassic black shales near a dolerite intrusion at Sassenfjorden, Spitsbergen: Chemical Geology, v. 25, no. 1/2, p. 53-65.

C) Purpose: to study the mineralogical and geochemical changes which take place when black shales are intruded by basaltic magmas.

Methods: petrography, chemical analyses (unspecified), XRD.

Results: the temperature of the intrusion was about 800°C, and thermally metamorphosed the sediments to the pyroxene-hornfels facies. After this episode, the hornfels were affected by metasomatic alteration. These solutions were enriched in Na, Si, Sr, Zr, Cr, V and Ni. The bulk chemical composition of sediments from 8 to 9 m below the dolerite-sediment boundary is probably altered to only a minor extent.

14 . A) Gen. Cat.--Minor intrusions, contact effects

B) Perregard, J.; Schiener, E. J., 1979, Thermal alteration of sedimentary organic matter by a basalt intrusive (Kimmeridgian shales, Milneland, East Greenland): Chemical Geology, v. 26, no. 3/4, p. 331-343.

C) Purpose: to investigate the thermal influence of a 4.5 m thick basalt dike upon the composition of the organic content of the surrounding shales and to determine the source potential of the shales.

Methods: compositional analysis of the saturated C₁₅₊ hydrocarbon fraction, gas chromatography, vitrinite reflectance measurements

Results: the heat effect from a basalt dyke is found to alter the composition of saturated and aromatic hydrocarbons in the surrounding immature shales up to a distance of about half the thickness of the dyke. Severe loss of organic matter is observed in the contact zone. The indigenous, thermally unaffected source material is dominated by isoprenoids and polycyclic alkanes among the saturated hydrocarbons.

15. A) Gen. Cat.--Minor intrusions

B) Reverdatto, V. V.; Pertsev, N. N.; Korolyuk, V. N., 1979, P_{CO_2} - T - evolution and origin of zoning in melilite during the regressive stage of contact metamorphism in carbonate-bearing rocks: Contributions to Mineralogy and Petrology, v. 70, no. 2, p. 203-208.

C) Purpose: to discuss the inner merwinite-bearing zone of exocontact marbles to demonstrate the distinct differences between the progressive and regressive stage of metamorphism.

Methods: petrography, electron microprobe.

Results: during the regressive stage of contact metamorphism, by the dolerite intrusive body, new akermanite-rich melilite and calcite were formed by replacement of merwinite and earlier gehlenitic melilite through participation of CO_2 .

16. A) Gen. Cat.--Minor intrusions

B) Hibbard, M. J., 1980, Indigenous source of late-stage dikes and veins in granitic plutons: Economic Geology, v. 75, no. 3, p. 410-423.

C) Purpose: to report on the construction of a model in which various igneous dikes, aplite-pegmatite dikes, veins of secondary K-feldspar and quartz, and veins containing ore minerals can be considered to have formed from the crystallizing pluton in which they occur, at or very close to the site of observation.

Methods: petrography.

Results: microveins of quartz and feldspar occurring in fractured crystals of granitic plutonic rocks are interpreted as marking the beginning of processes that, under the appropriate mechanical conditions, lead to the development of: 1) various finer grained or porphyry dikes, 2) aplite dikes, 3) aplite-pegmatite dikes and pods 4) veins of secondary K-feldspar (commonly orthoclase), 5) veins of secondary biotite, 6) quartz veins, and, 7) veins with various ore and alteration minerals.

17 . A) Gen. Cat.—Minor intrusions

B) Cambell, I. H.; Franklin, J. M.; Gorton, M. P.; Hart, T. R.; Scott, S. D.,
1981, The role of subvolcanic sills in the generation of massive sulfide
deposits: Economic Geology, v. 76, no. 8, p. 2248-2253.

C) Purpose: to test whether subvolcanic sills are an integral part of the ore
forming process and are, therefore, mandatory for the formation of massive
sulfide deposits.

Methods: chemical analyses (XRF, INAA).

Results: Geochemical data indicates that the subvolcanic sills in the
Sturgeon Lake and Kam Kotia areas are the magma chambers which fed the
ore-associated felsic volcanics.

18 .A) Gen. Cat.--Minor intrusions, dikes

B) Papezik, V. S.; Barr, S. M., 1981, The Shelburne dike, an early Mesozoic diabase dike in Nova Scotia: mineralogy, chemistry, and regional significance: Canadian Journal of Earth Science, v. 18, no. 8, p. 1346-1355.

C) Purpose: to present new chemical and mineralogic data on the Shelbourne dike.

Methods: petrography, chemical analyses, K-Ar isochron method for dating.

Results: the Shelburne dike is tholeiitic and quartz normative, and its chemistry resembles that of the Palisades Sill of New Jersey. Contact effects are not discussed.

19. A) Gen. Cat.--Dikes

B) Platt, R. G.; Mitchell, R. H., 1982, The marathon dikes: ultrabasic lamprophyres from the vicinity of McKellar Harbour, N. W. Ontario: *American Mineralogist*, v. 67, no. 9 and 10, p. 907-916.

C) Purpose: to describe a previously unrecognized group of lamprophyres, with alnöitic affinities, from the McKellar Harbour shoreline of Lake Superior.

Methods: petrography, electron microprobe.

Results: the McKellar Harbour dikes are characterized by the mineral assemblage phlogopite-olivine-spinel-perovskite-apatite-carbonate (calcite). Mineralogy indicates no affinities with Kimberlites.

20. A) Gen. Cat.--Minor intrusions, sills

B) Raudsepp, M.; Ayres, L. D., 1982, Emplacement and differentiation of an Archaen subvolcanic metapyroxenite-metagabbro sill in the Favourable Lake area, northwestern Ontario: Canadian Journal of Earth Sciences, v. 19, no. 4, p. 837-858.

C) Purpose: to discuss the general nature, emplacement, and differentiation of one of these multiple sills.

Methods: geologic mapping, petrography, chemical analyses.

Results: alteration-induced chemical changes in these samples are relatively minor.

22. A) Gen. Cat.--minor intrusions

B) Southwick, D. L.; and Day, W. C., 1983, Geology and petrology of Proterozoic mafic dikes, north-central Minnesota and western Ontario: Canadian Journal of Earth Science, v. 20, no. 4, p. 622-638.

C) Purpose: to describe the geology of this Proterozoic mafic dike swarm.

Methods: geologic mapping, chemical analyses, petrography.

Results: the dike magma is inferred to have been emplaced at a temperature of about 1085°C, to have quenched against the cool walls in a matter of minutes, and to have remained partly liquid in the central parts of large dikes for 40 years or more. The ubiquitous alteration of the dikes is a deuteric phenomenon.

23. A) Gen. Cat.--Minor intrusions

B) Springer, N.; Pedersen, S.; Bridgewater, D.; Glassley, W. E., 1983,
One dimensional diffusion of radiogenic ^{87}Sr and fluid transport
of volatile elements across the margin of a metamorphosed
Archaean basic dyke from Saglek, Labrador: Contributions to
Mineralogy and Petrology, v. 82, no. 1, p. 26-33.

C) Purpose: to describe the chemical changes across a gneiss-amphibolite
dike contact affected by greenschist facies metamorphism.

Methods: petrography, chemical analyses (XRF, gas chromatography),
Rb and Sr isotopes.

Results: the chemical changes across the contact can be described as
a combination of two kinetic processes: 1) diffusion in which there
has been exchange between a fluid phase enriched in ^{87}Sr with Sr already
present in the major mineral phases; and 2) fluid transport which was
responsible for the enrichment of the dike margin in alkalies, total
Sr, LREE, Ti and volatiles.

MISCELLANEOUS

1 . A) Gen. Cat.--Thermal expansion, albite

B) Stewart, D. B.; vonLimbach, D., 1967, Thermal expansion of low and high albite: *American Mineralogist*, v. 52, no. 3 and 4, p. 389-413.

C) Purpose: to present complete data for the thermal expansion of low albite and sufficient data to estimate the thermal expansion of high albite to about 1000^o.

Methods: XRD with heating stage.

Results: various expressions of the volume thermal expansion of each polymorph are presented. The percent volume expansions of both polymorphs are almost identical, but the coefficients of thermal expansion are not. The effect of temperature on the cell angles of both polymorphs is the same as that caused by solid solution with potassium feldspar.

2 . A) Gen. Cat.--Radon

B) Dyck, W., 1968, Radon-222 emanations from a uranium deposit:

Economic Geology, v. 63, no. 3, p. 288-291.

C) Purpose: to present the results of a preliminary survey of radon emanations in soil gas over a uranium ore deposit near Bancroft, Ontario.

Methods: soil gas sampling, gamma ray activity measurements.

Results: this paper emphasizes the exploration aspects of radon emanations. The results demonstrate the principle of radon emanation from the surface of a uranium ore body.

3. A) Gen. Cat.--Phosphates

B) Coppens, R.; Bashir, S.; Richard, P., 1977, Radioactivity of Al Hasa phosphates: A preliminary study: Mineralium Deposita, v. 12, no. 2, p. 189-196.

C) Purpose: to investigate the radioactivity of the Al Hasa phosphates.

Methods: chemical analyses (fluorimetry, alpha-autoradiography, gamma and alpha -spectrometry, calorimetry)

Results: evidence suggests that U in these phosphates had two origins.

Lower U contents could be fixed by certain processes that have a direct or indirect relation with P_2O_5 . Meanwhile, the surplus of U in the higher U contents should be formed by a different process. The surplus could be captured by clays or organic matter of various sorts whenever present in considerable amounts.

4 . A) Gen. Cat.--Diagenesis

B) Baragar, W. R. A. ; Plant, A. G.; Pringle, G. J.; Schau, M., 1979,
Diagenetic and postdiagenetic changes in the composition of an
Archean pillow: Canadian Journal of Earth Sciences, v. 16, no. 11,
p. 2102-2121.

C) Purpose: to evaluate the chemical changes that affect submarine
volcanic rocks as a result of seafloor alteration and subsequent
metamorphism.

Methods: petrography, chemical analyses, electron microprobe.

Results: the uneven distribution of elements within the pillow
resulting from the three events (magmatism, diagenesis, and meta-
morphism) can be largely accounted for by internal rearrangement of
elements: exchange with the external environment: notably seawater -
was probably minor.

5 . A) Gen. Cat.--Water chemistry

B) Hubert, A. E.; Chao, T. T., 1979, Multielement analysis of natural waters for hydrogeochemical prospecting by X-ray fluorescence following preconcentration and filter deposition: Economic Geology, v. 74, no. 7, p. 1669-1672.

C) Purpose: to develop an XRF method to determine several metals in water using a preconcentration procedure.

Methods: XRF.

Results: The X-ray method is reproducible and results compare favorable with those obtained by other chemical methods.

6 . A) Gen. Cat.--Uranium deposits

B) Lindroos, H.; Smellie, J., 1979, A stratabound uranium occurrence within Middle Precambrian ignimbrites at Duobblon, No. 5, p. 1118-1130.

C) Purpose: to present preliminary results of a uranium ore prospecting program.

Methods: geologic mapping, isotopic dating, petrography, scanning microscope, chemical analyses.

Results: the highest U enrichments are generally associated with high Pb, V, and Mo, but the correlation is poor in detail.

1. A) Gen. Cat.--Properties of bedded salts

B) Le Comte, P., 1965, Creep in rock salt: Journal of Geology, v. 73, no. 3, p. 469-484.

C) Purpose: study creep in rock salt under various conditions.

Methods: Ames dial gauge with 0.0001 inch divisions.

Results: an increase in temperature or stress difference increases creep rate considerably, while increases in confining pressure or grain size decrease creep rate slightly. Activation energy for creep ranges from 125,000 cal/mol at 29°C, to 30,000 cal/mol at 300°C. Creep curves are defined by the equation $\epsilon = A + Bt^n$, where ϵ is deformation at time t after application of load, and A, B, and n are constants ($0 < n < 1$).

2. A) Gen. Cat.--Salt deposits, Gnome nuclear explosion

B) Kahn, J. S.; Smith, D. K., Mineralogical investigations in the debris of the Gnome event near Carlsbad, New Mexico: *American Mineralogist*, v. 51, no. 7, p. 1192-1199, 1966.

C) Purpose: to determine any systematic association between the mineral assemblages and specific activities at the site of the Gnome underground nuclear explosion.

Methods: chemical analyses, Debye-Scherrer x-ray camera, electron microprobe.

Results: from this data it is apparent that most alpha, beta, and gamma activity is associated with the silicates olivine and kirschsteinite. Electron microprobe analysis suggests kirschsteinite is found with all olivine material, since Ca is associated with Fe and Mg at all times. The exact location of the actinides is still in doubt. Based on the size of their atomic radii, it appears unlikely that the actinides are trapped interstitially within the silicate crystallites.

3 . A) Gen. Cat.--Basalt, altered; zeolites

B) Harada, K.; Iwamoto, S.; Kihara, K., 1967, Erionite, phillipsite and gonnardite in the amygdales of altered basalt from Mazé, Niigata Prefecture, Japan: American Mineralogist, v. 52, no. 11 and 12, p. 1785-1794.

C) Purpose: to describe erionite in some detail together with phillipsite, gonnardite, natrolite, and analcime.

Methods: petrography, chemical analyses, XRD, infrared absorption spectrometry.

Results: erionite, phillipsite, and gonnardite from the altered basalts were described, and erionite was found to be hexagonal.

4. A) Gen. Cat.—tuffs, zeolitized; Nevada Test Site

B) Riecker, R. E.; Rooney, T. P., 1967, Shear strength and weakening of zeolitized tuffs from the Nevada Test Site, Nevada: *American Mineralogist*, v. 52, no. 7 and 8, p. 1174-1178.

C) Purpose: to determine the shear strength and mechanical behavior of NTS tuffs.

Methods: shear tests, chemical analyses.

Results: the weakening observed in shear tests on tuff may be accounted for by the dehydration of clinoptilolite with a consequent reduction in effective confining pressure caused by the development of a high pore pressure in the sample. The strength of the rocks may be greatly influenced by the presence of water.

5 . A) Gen. Cat.--tuffs, analcime

B) Iijima, A.; Hay, R. L., 1968, Analcime composition in tuffs of the Green River Formation of Wyoming: American Mineralogist, v. 53, no. 1 and 2, p. 184-200.

C) Purpose: to determine the Si/Al ratio of enough samples to show more precisely the pattern of analcime composition in tuffs and its relationship to that of saline minerals and authigenic alkali feldspars and quartz.

Methods: petrography, XRD, electron microprobe.

Results: analcime has extensively reacted to form alkali feldspars in the Green River Formation, and new data show that siliceous analcime crystals become partly desilicated in their reaction to form feldspars. Stratigraphic position of most of the altered analcime in and near the margin of the saline facies suggests that salinity has played a major role in the reaction of analcime to form alkali feldspars.

6 . A) Gen. Cat.--Alteration of basalt

B) Smith, R. E., 1968, Redistribution of major elements in the alteration of some basic lavas during burial metamorphism: Journal of Petrology, v. 9, p. 191-219.

C) Purpose: to analyze and describe alteration effects in some basic lavas due to burial metamorphosis.

Methods: petrography and chemical analysis.

Results: the alteration minerals are characteristic of the prehnite-pumpellyite facies and are thought to have formed during the metamorphism. Chemical departure from the original lava compositions is described and defined as two diverging trends.

7. A) Gen. Cat.--Behavior of salts in geomeia

B) Jacoby, C. H., 1969, Correlation, faulting, and metamorphism of Michigan and Appalachian Basin salt: American Association of Petroleum Geologists Bulletin, v. 53, no. 1, p. 136-154.

C) Purpose: describe the stratigraphy and structures of the Michigan and Appalachian Basin salts.

Methods: electric log and mine data.

Results: faulting can occur without damage by groundwater. Intrusion of a peridotite dike and sill elevated the temperature of the salt in the Ludlowville area to cause flow. In the Cleveland mine area, recrystallization has been by both tectonic means and solution entrapment. Horizontal stresses have formed graben-like structures. Tension cracks are filled with metamorphosed salt.

8. A) Gen. Cat.--Salt deposits, loeweite

B) Fang, J. H.; Robinson, P. D., 1970, Crystal structure and mineral chemistry of double salt hydrates: II. The crystal structure of loeweite: American Mineralogist, v. 55, no. 3 and 4, p. 378-386.

C) Purpose: to resolve the number of water molecules in the unit cell and the ratio of $\text{Na}_2\text{SO}_4/\text{MgSO}_4$ in the formula.

Methods: Buerger diffractometer measurements, mathematical analyses.

Results: the crystal structure of loeweite, $6\text{Na}_2\text{SO}_4 \cdot 7\text{MgSO}_4 \cdot 15\text{H}_2\text{O}$, can be described as corner-sharing zig-zag chains of Mg octahedra and S tetrahedra, emanating in six directions from the corners of the Mg octahedron located at the center of the unit cell. The two non-equivalent Na atoms are in 7-fold coordination with the Na-O distances ranging from 2.31 to 2.87 Å. The Mg-O distances vary within a small range of 2.01 to 2.12 Å. The S-O distances in the two independent SO_4 groups average 1.47 and 1.48 Å respectively, while the mean distance in the disordered SO_4 group is 1.60 Å.

9. A) Gen. Cat.--Salt deposits

B) Moore, G. W., 1971, Geologic significance of the minor-element composition of marine salt deposits: *Economic Geology*, v. 66, no. 1, p. 187-191.

C) Purpose: to evaluate the controlling factors of evaporite deposition and to give the average chemical composition of evaporite deposits.

Methods: chemical analyses (wet chemistry, emission spectrography)

Results: the similar composition of rock salt of differing ages suggests that the ratio between ions in sea water has remained approximately constant since Cambrian time. Certain elements, such as strontium and boron, are depleted in marine halite rock because they are deposited respectively earlier and later in the evaporation sequence. Lead is enriched a thousandfold, possibly because of heavy-metal concentration by microorganisms.

10. A) Gen. Cat.--salt deposits

B) Wardlaw, N. C., 1972, Unusual marine evaporites with salts of calcium and magnesium chloride in Cretaceous Basins of Sergipe, Brazil: Economic Geology, v. 67, no. 2, p. 156-168.

C) Purpose: to describe the Cretaceous (Aptian) evaporites of Sergipe, Brazil, and to explain the unusual circumstances in which tachyhydrite may have been formed and preserved.

Methods: chemical analyses (AA), petrography.

Results: the very regular upward increase of Br and the constancy of Sr through the upper zone of tachyhydrite could only have been achieved where crystallization was uninterrupted by sudden influxes of marine waters and where the primary salts were preserved without alteration.

11. A) Gen. Cat.--Basalt alteration

B) Dasch, E. J.; Hedge, C. E.; Dymond, J., 1973, Effect of sea water interaction on strontium isotope composition of deep-sea basalts: Earth and Planetary Science Letters, v. 19, p. 177-183.

C) Purpose: to determine whether higher $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in older basalts are raised by low temperature interaction with strontium dissolved in sea water.

Methods: to study the problem of alteration and contamination by analysis of H_2O , K, Rb, and Sr concentrations and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in three types of ocean tholeiites. 1) fresh pillow basalts 2) holocrystalline basalts and 3) low temperature weathered basalts. H_2O was analyzed by a Dupont H_2O analyzer . K was analyzed by atomic adsorption spectrometry; Sr by x-ray fluorescence analysis; Rb by isotope dilution; $^{87}\text{Sr}/^{86}\text{Sr}$ by mass spectrometer.

Results: the data points to long-term low-temperature formation of alteration minerals as the most reasonable process for the isotopic modification.

12 . A) Gen. Cat.—Basalt alteration

B) Ludden, J. N.; Thompson, G., 1973, An evaluation of the behavior of the rare earth elements during the weathering of sea-floor basalt: Earth and Planetary Science Letters, v. 43, p. 85-92.

C) Purpose: to evaluate REE behavior during weathering of sea-floor basalts.

Methods: REE were analyzed in fresh and altered tholeiitic basalts sampled during dredging at 23°N in the Atlantic Ocean and covering a time span of 0 to 57 million years.

Results: altered basalt interiors to palagonitized rinds in individual pillow samples indicate significant mobility of the light REE: Some elements are enriched 4 orders of magnitude in rinds relative to interiors. The heavy REE show no selective mobilization and can be used in a normalization procedure which indicates that the light REE are enriched in altered interiors relative to fresh interiors of the basalts. Cesium behaves anomalously and accords with either its abundance in seawater or its fractionation from seawater during formation of ferromanganese deposits.

13 . A) Gen. Cat.--Basalt

- B) Sheppard, R. A.; Gude, A. J., III; Desborough, G. A.; White, J. S., Jr.,
1974, Levgyne-offretite intergrowths from basalt near Beech
Creek, Grant County, Oregon: *American Mineralogist*, v. 59,
no. 7 and 8, p. 837-842.

- C) Purpose: to describe levgyne-offretite intergrowths in basalts from
Beech Creek, Oregon.

Methods: petrography, electron microprobe, XRD.

Results: the offretite from Beech Creek has clearly formed later than
the levgyne, and, at least locally, has replaced the levgyne. Most clay
minerals and zeolites in the vesicles of Cenozoic basalts formed after
crystallization and cooling of the basalts. The Beech Creek zeolites
are probably no exception, and the constituents necessary for the
zeolites were probably dissolved from the Picture Gorge Basalt by
cool meteoric water.

14. A) Gen. Cat.--Salt bed alteration

B) Swenson, F. A., 1974, Rates of salt solution in the Permian Basin:

Journal of Research of the USGS, v. 2, no. 2, p. 253-257.

C) Purpose: to determine rates of solution of salts in the Permian Basin for the purpose of finding long term safe storage of radioactive materials (solution of the salt would imperil safe storage)

Methods: USGS records of streamflow and chemical quality of water, computations of NaCl discharges of numerous sub-basins and saline springs were compiled.

Results: the compilations were made into a map showing discharge rates in tons per day.

15 . A) Gen. Cat.--Basalt, amphiboles

B) Allen, J. C.; Boettcher, A. L.; Manland, G., 1975, Amphiboles in andesite and basalt: I. Stability as a function of P-T- f_{O_2} : American Mineralogist, v. 60, no. 11 and 12, p. 1069-1085.

C) Purpose: to experimentally establish the stabilities of amphiboles in an andesite, three basalts, and an olivine nephelinite in the presence of H_2O vapor at values of oxygen fugacity (f_{O_2}) approximating those of Fe_3O_4 - Fe_2O_3 , Ni-NiO, and Fe_3O_4 -FeO, from 10 to 36 kbar, determining the pressures at which amphibole-bearing assemblages transform to garnet-bearing assemblages, i.e., at depths (475-100 km) in the Earth.

Methods: chemical analyses, experimental petrology, electron microprobe.

Results: the thermal stability decreases with increasing activity of silica in the parent rocks.

Maximum thermal stability of amphibole occurs at $1090^{\circ}C$ at 13 kbar in the Hualalai alkali basalt. Maximum pressure stability occurs at 31.5 kbar at a temperature of $1030^{\circ}C$ in the olivine nephelinite.

16. A) Gen. Cat.--Basalt alteration

B) Furnes, H., 1975, Experimental palagonitization of basaltic glasses of varied composition: Contributions to Mineralogy and Petrology, v. 50, p. 105-113.

C) Purpose: to determine rates and mechanisms of palagonitization of basalt glass.

Methods: the rates of palagonitization of 3 chemically different types of basalt glass were determined by sealing the specimens in capsules, $\frac{1}{2}$ with sea water and $\frac{1}{2}$ with deionized H_2O and left for varying times.

Results: rates are given relative to their composition, temperature, and times involved. Mechanisms for variations in rate are discussed.

17 . A) Gen. Cat.--Alteration of basalt

B) Lawrence, J. R.; Gieshes, J.M.; Broecker, W. S., 1975, Oxygen isotope and cation composition of DSDP pore waters and the alteration of Layer II basalts: Earth and Planetary Science Letters, v. 27, p. 1-10.

C) Purpose: to determine cause of composition gradient of pore fluids from cores of Deep Sea Drilling Project (DSDP)

Methods: analysis of $^{18}\text{O}/^{16}\text{O}$, Ca^{2+} , K^{+} and Mg^{2+} concentrations along cores taken in the DSDP.

Results: decreases with depth of 1-3% in the pore water $^{18}\text{O}/^{16}\text{O}$ and increases with depth of up to four times the seawater concentration in pore water Ca^{2+} were observed in the DSDP. This is attributed to alteration of basalt in Layer II of the ocean floor and secondarily to alteration of volcanic ash in the sediments. Ca^{2+} is being added to the ocean while ^{18}O and probably K^{+} and Mg^{2+} are being removed, due to these processes.

18. A) Gen. Cat.--Alteration of basalt

B) Kastner, M.; Gieshes, J. M., 1976, Interstitial water profiles and sites of diagenetic reactions Leg 3J, DSDP, Bellingshausen

Plain: Earth and Planetary Science Letters, v. 33, p. 11-20.

C) Purpose: to find sites that will bear further mineralogical and chemical investigations, and then study them.

Methods: finding discrepancies between predicted and observed interstitial water profiles were used to identify sites of reaction for further mineralogical and chemical investigation.

Results: in the basalt, weathering of pyroxene and plagioclase and the formation of celadonite, smectite, calcite and goethite are probably responsible for the observed Ca^{2+} , Mg^{2+} and K^{+} interstitial water gradients below the silicification zone.

19.A) Gen. Cat.--Basalts, alteration

B) Andrews, A. J., 1977, Low temperature fluid alteration of oceanic layer
2 basalts, DSDP Leg 37: Canadian Journal of Earth Sciences, v. 14,
no. 4, p. 911-926.

C) Purpose: to provide some insight into the chemical nature of low
temperature seawater-basalt interaction.

Methods: petrography, electron microprobe, XRD, chemical analyses (XRF, AA)

Results: detailed examination of the mineralogy and chemistry of oxidative
alteration suggests that during low temperature seawater-basalt interaction,
basalt experiences a net gain in O, total Fe and K_2O , while SiO_2 and MgO
appear to have been locally remobilized. These trends are generally consistent
with the distribution of secondary phases. The distributions of Mn, Cu,
Ni, Zn, Co, and Sr do not appear to have been significantly affected during
this process.

20. A) Gen. Cat.--Basalts, alteration

B) Baragar, W. R. A.; Plant, A. G.; Pringle, G. J.; Schau, M., 1977,
Petrology and alteration of selected units of Mid-Atlantic Ridge
basalts sampled from sites 332 and 335, DSDP: Canadian Journal
of Earth Sciences, v. 14, no. 4, p. 837-874.

C) Purpose: to determine the effect of sea floor weathering on the chemical
composition of the primary basalts.

Methods: petrography, electron microprobe.

Results: Palagonitization results in gains in K, Fe, Ti, and Cl, and
losses in Ca, Mg, and Na, but net gains and losses in the other sites
are less certain. Hydration and oxidation of iron invariably accompany
development of volatile-bearing phases, but there is no correlation
between these parameters and variation in content of the other analyzed
elements.

21. A) Gen. Cat.--Basalts, alteration or Basalts, uranium

B) Mitchell, W. S.; Aumento, F., 1977, Uranium in oceanic rocks: DSDP Leg 37:

Canadian Journal of Earth Sciences, v. 14, no. 4, p. 794-808.

C) Purpose: to document the variations in the distribution of uranium through the section of oceanic crust drilled during Leg 37 of the Deep Sea Drilling Project.

Methods: fission track analyses, petrography.

Results: this investigation revealed that both primary and secondary variations in uranium concentration can be observed. Uranium enrichment occurs on a very localized scale within the basalts, and is mainly confined to highly altered areas of basalt surrounding veins or fractures and to zones of palagonitized sideromelane.

22. A) Gen. Cat.--Alteration of basalt

B) Scheidegger, K. F.; Stakes, D. S., 1977, Mineralogy chemistry and crystallization sequence of clay minerals in altered tholeiitic basalts from the Peru Trench: Earth and Planetary Science Letters, v. 36, p. 413-422.

C) Purpose: to study low temperature alteration of basalt

Methods: chemical and x-ray diffraction analysis of materials in pore spaces of moderately altered tholeiitic pillow basalts from the Peru Trench was made.

Results: Fe-rich saponite and montronite are the dominant alteration products plus small amounts of serpentine, illite, calcite and celadonite. Montmorillonite, the dioctahedral aluminous smectite was not detected. It is suggested that the first interstitial fluids were slightly oxidizing and Fe-rich, the second ones were more oxidizing and Mg-rich and the final ones were generally Ca-rich. The presence of calcite and smectites indicates that alkaline conditions prevailed. High CO₂ and H₂O activity are thought to have been responsible for the alteration of mafic minerals and interstitial residue and the relative freshness of plagioclase. Without plag alteration smectites will be non-aluminous.

23. A) Gen. Cat.--Basalt alteration

B) Bacon, M. P., 1978, Radioactive disequilibrium in altered mid-oceanic basalts: Earth and Planetary Science Letters, v. 39, p. 250-254.

C) Purpose: to determine the extent to which uranium migration is revealed by radioactive disequilibria in the products of basalt alteration by seawater.

Methods: both low temperature and high temperature weathered samples were analyzed for U and Th isotope compositions.

Results: A young basalt sample dredged from the Mid-Atlantic ridge shows a ^{234}U excess and a ^{230}Th deficiency resulting from addition of seawater U during weathering at seafloor temperature. Two older samples have acquired substantial amounts of U from seawater but are depleted in ^{234}U , indicating preferred leaching of this isotope. Hydrothermally altered samples suggest that some U loss may have occurred. Isotope effects of preferred ^{234}U leaching, however, are obscured by secondary addition of seawater at lower temperatures.

- 24 . A) Gen. Cat.--Basalt, interstitial glass or chlorophaeite
- B) Meyer, P. S.; Sigurdson, H., 1978, Interstitial acid glass and chlorophaeite in Iceland basalts: Lithos, v. 11, no. 3, p. 231-241.
- C) Purpose: to study rhyolitic glass and chlorophaeite in Icelandic basalts.
- Methods: petrography, electron microprobe
- Results: this study indicates that an immiscibility relationship between the interstitial phases in Icelandic dikes is unlikely and that the chlorophaeite represents a late-stage deuteric alteration product.

25 . A) Gen. Cat.—Basalt alteration

B) Andrews, A. J., 1979, On the effect of low-temperature seawater basalt interaction on the distribution of sulfur in oceanic crust, layer 2: Earth and Planetary Science Letters, v. 46, p. 68-80.

C) Purpose: to find the mechanism for deposition of sulfur deposits in Layer 2 oceanic crust.

Methods: detailed geochemical and petrological examination of layer 2 basalts recovered during leg 37 of the DSDP.

Results: the original distribution, form and abundance of igneous sulfide have been profoundly altered during low grade oxidative diagenesis. The result is a remobilization of igneous sulfide forming secondary pyrite with the bulk loss of sulfur of about 50-60% of the original igneous value.

26 . A) Gen. Cat.--Basalt alteration

B) Chowdhuri, A. N., 1982, Smectite, zeolite, biotite and apatite in the Corallian (Oxfordian) sediments of the Baulking area in Berkshire, England: Geological Magazine, v. 119, no. 5, p. 487-496.

B) Purpose: to describe and determine the origin of the sediments of the Baulking area, England.

Methods: weighted integrated diffraction peak method, x-ray diffraction, thin section and electron microscopy.

Results: the association is believed to be of volcanic origin, that is altered volcanic ash. Mineral associations are given but no detailed chemical data.

27. A) Gen. Cat.--Basalt

B) Deutsch, W. J.; Jenne, E. A.; Krupka, K. M., 1982, Solubility equilibria in basalt aquifers: the Columbia Plateau, eastern Washington, U. S. A. In: G. W. Bird and W. S. Fyfe (Editors), Geochemistry of Radioactive Waste Disposal: Chemical Geology, v. 36, no. 1/2, p. 15-34.

C) Purpose: to utilize geochemical modeling to interpret solubility controls for major ions in aquifers in the Columbia Plateau basalts in eastern Washington.

Methods: petrography, groundwater analyses, geochemical modeling

Results: results indicate that calcite is at equilibrium with the basalt groundwaters. In addition, amorphous phases, such as ferric hydroxide, allophane and SiO_2 (a, gl), apparently play an important role at ambient temperatures in limiting the maximum concentration of dissolved Fe, Al, and Si in the groundwaters. Detailed mineralogical studies are needed to ascertain if certain of the solid crystalline phases (sepiolite, fluorite, and MnHPO_4), which similarly compute to be in equilibrium with these water samples, are in fact present as secondary minerals in Columbia Plateau basalt.

28. A) Gen. Cat.--Fractured igneous intrusions

B) Stone, E.; Kamineni, D. C., 1982, Fractures and fracture infillings of the Eye-Dashwa Lakes pluton, Atikokan, Ontario: Canadian Journal of Earth Sciences, v. 19, no. 4, p. 789-803.

C) Purpose: to describe fracture and fracture infillings of the Eye-Dashwa Lakes pluton as a fundamental basis for assessing the waste disposal concept.

Methods: petrography, determination of fractures and fracture filling material in the pluton, using a grid and drilling machines.

Results: movement of radionuclides through fractures with alteration minerals adjacent to fractures is likely to be slower than through fractures with no wall-rock alteration or filling materials.

29. A) Gen. Cat.--Kinetics

B) Walton, F. B.; Melnyk, T. W.; Abry, R. G.; Fleury, K., 1982, The determination of nuclide-geologic media reaction kinetics using mixing-cell contactors. In: G. W. Bird and W. S. Fyfe (Editors), Geochemistry of Radioactive Waste Disposal: Chemical Geology, v. 36, no. 1/2, p. 155-178.

C) Purpose: to discuss a laboratory technique (the use of the mixing-cell apparatus) which is free of the interference of hydraulic effects and is sensitive enough to measure slow kinetic processes.

Methods: use of mixing cell contactor, sorption studies

Results: the mixing-cell technique provides a method of determining equilibrium distribution coefficients (K_a) from estimates of adsorption and desorption rate constants (i.e. k_1 and k_2 , respectively). The mixing-cell technique is more sensitive than the batch coupon technique for measuring K_a of nuclides with slow sorption kinetics.

30 . A) Gen. Cat.--Basalts, alteration

B) DeVore, G. W., 1983, The influence of submarine weathering of basalts on their partial melting during subduction: *Lithos*, v. 16, no. 3, p. 203-213.

C) Purpose: to discuss the idea that weathered basalts may be important source materials for island arc volcanics.

Methods: review of literature (chemical analyses)

Results: recalculations of 278 analyses from the literature of altered basalts result in increased quartz contents relative to fresh basalt in most examples. The increased quartz contents result in mineral assemblages that have enhanced potentials to generate andesitic partial melts.

31 . A) Gen. Cat.--Effect of alteration on pore structure

B) Katsube, T. J.; Kamineni, D. C., 1983, Effect of alteration on pore structure of crystalline rocks: Core samples from Atikokani, Ontario: Canadian Mineralogist, v. 21, p. 637-46.

C) Purpose: alteration of pore spaces may alter rate of radioactive nuclide migration.

Methods: analysis of results of porosity, electrical and permeability measurements, effective porosity, connecting porosity, tortuosity, and permeability are calculated.

Results: alteration reduced the connecting porosity and permeability and increased the tortuosity.

32. A) Gen. Cat.--Delaware Basin

B) Hills, John M., 1984, Sedimentation, tectonism, and hydrocarbon generation in Delaware Basin, west Texas and southeastern New Mexico: American Association of Petroleum Geologists Bulletin, v. 68, no. 3, p. 250-267.

C) Purpose: "add to the history of this basin and to point out the influence of sedimentation and tectonism on oil and gas generation and accumulation."

Methods: analysis of well log data, geologic structure contour maps, cross-sections and stratigraphic sections, Rb-Sr and K-Ar data (not this author's).

Results: the Delaware Basin originated in the Proterozoic, persisting until the end of the Permian. Overall, a lack of tectonic activity with the exception of eastward tilting along fault zones on east side, and formation of anticlines during Carboniferous. 4 periods of hydrocarbon generation: Mid. Ord., L. Dev. and E. Miss., Mid. Penn., E. and Mid. Permian.

33. A) Gen. Cat.--Salt deposits

B) Roedder, E., 1984, The fluids in salt: *American Mineralogist* , v. 69,
no. 5 and 6, p. 413-439.

C) Purpose: to review the current status of the study of the types of fluid present in salt, their origin and evolution, and their significance to understanding the geological processes that have occurred. This paper also describes how salt studies are pertinent to the engineering design of a nuclear waste storage site in salt.

Methods: fluid inclusion studies, stable isotope studies (O,H)

Results: migration of fluid inclusions up the thermal gradient established by a radioactive waste canister will tend to concentrate at the canister the fluids from inclusions from some distance around. Estimates of the rates and total volumes of fluid that must be dealt with in a repository design are subject to rather large uncertainties.

34. A) Gen. Cat.--Properties of salt rocks.

B) Wilgus, C. K., and Holser, W. T., 1984, Marine and non-marine salts of western interior, U.S.: American Association of Petroleum Geologists Bulletin, v. 68, no. 6, p. 765-767.

C) Purpose: study the use of evaporite geochemistry in determining genesis.

Methods: colorimetric method on Beckman DK-20 spectrophotometer in order to quantify ppm Br. Also performed on Bausch and Lomb Spectronic 20 using ASTM methods.

Results: quite a variability in Br content between Williston and Alliance basin Permian salts. Alliance is clearly precipitated from normal marine brines (Br = 76-98 ppm) Williston is apparently second cycle (non-marine) (Br = 0-70ppm). Rustler and Salado formations in Delaware Basin show greatest range (Br = 35-190ppm) but were precipitated from marine brines. Higher Br concentration toward potash facies.

1 . A) Gen. Cat.--Skarn deposits

B) Salotti, C. A., 1965, Mineralogy and paragenesis of the Cotopaxi, Colorado, Cu-Zn skarn deposit: American Mineralogist, v. 50, no. 9, p. 1179-1212.

C) Purpose: to conduct a detailed investigation of the Cotopaxi deposit.

Methods: petrography, structural studies.

Results: the overall process of formation, although complex, can be separated into the following distinct stages: amphibolite formation, almost exclusively confined to the formation of silicate minerals; pegmatoid stage, mainly the formation of silicate minerals, but some oxides, aluminates, tungstates; ore deposition, successive formation of sulfides of iron, zinc, copper, and lead; retrograde mineralization, conversion of anhydrous to hydrous silicates and the alteration of pyrrhotite to pyrite-magnetite-marcasite; and surficial weathering.

2 . A) Gen. Cat.--Skarn deposits

B) Buseck, P. R., 1967, Contact metasomatism and ore deposition: Tem Piute, Nevada: Economic Geology, v. 62, no. 3, p. 331-353.

C) Purpose: to investigate the origin and environment of deposition of the ore minerals along with features of particular geologic interest.

Methods: petrography, XRD, pyrrhotite geothermometry.

Results: at Tem Piute a barren stock is separated from unmineralized limestone and hornfels by a narrow zone of banded skarn, the banding reflecting minor but original compositional differences within the sediments. Within this skarn zone is a wide variety of ore minerals - pyrite, chalcopyrite, pyrrhotite, magnetite, marcasite, sphalerite, molybdenite, galena, hematite, galenobismutite, cosalite, bismuthinite, and native bismuth, as well as scheelite - an unusually complex suite for a contact metasomatic deposit.

3 . A) Gen. Cat.--Skarn deposits

B) Némec, D., 1968, Phosphorous in regionally metamorphosed skarns of the Bohemian Massif and its genetic meaning: Mineralium Deposita, v. 3, no. 4, p. 386-394.

C) Purpose: to conduct an investigation of phosphorous in regionally metamorphosed skarns of the Bohemian Massif.

Methods: chemical analyses (colorimetry)

Results: the P-contents of the rocks from the cores of the skarn bodies studied equal those determined in relic carbonate rocks from which they probably originated, whereas the P-contents of the rocks from the outer parts of the skarn bodies correspond to those found in the enclosing rocks.

4 . A) Gen. Cat.--Skarn minerals, Sc-content

B) Frondel, C., 1970, Scandium content of ore and skarn minerals at Franklin, New Jersey: *American Mineralogist*, v. 55, no. 5 and 6, p. 1051-1054.

C) Purpose: to describe the scandium content of ore and skarn minerals at Franklin.

Methods: chemical analyses (neutron activation)

Results: skarn zones in the Franklin ore body contain scandium chiefly in andradite (5-50 ppm), pyroxene (12-95 ppm), and amphibole (18-40ppm), with very small amounts present in hendricksite, rhodonite, hyalophae, and idocrase. The partition ratios for various mineral pairs in different specimens vary widely, indicating non equilibrium conditions.

5. A) Gen. Cat.--Skarns, minerals; Skarns, Fassaite
- B) Rao, A. T.; Rao, M. V., 1970, Fassaite from a calc-silicate skarn vein near Gondivalasa, Orissa, India: *American Mineralogist*, v. 55, no. 5 and 6, p. 975-980.
- C) Purpose: to describe fassaite from a calc-silicate vein occurring in the limestones of the khondalite group of Eastern Ghats near Gondivalasa.
- Methods : petrography, chemical analyses, XRD.
- Results: all the features described suggest a metasomatic skarn vein formation in the limestones by the influx of hydrothermal solutions enriched in silica, alumina, magnesium, iron and water. The source of these elements may be a later intrusive granite.

6 . A) Gen. Cat.— Skarns, diopside and actinolite

B) Hietanen, A., 1971, Diopside and actinolite from skarn, Clearwater County, Idaho: *American Mineralogist*, v. 56, no. 1 and 2, p. 234-239.

C) Purpose: to determine the exact compositions of the coexisting diopside and actinolite.

Methods: petrography, chemical analyses, spectrographic analyses.

Results: chemical and spectrographic analyses of coexisting actinolite and diopside indicate nearly equal distribution of all other elements except calcium. Calculated $[Ca/Fe + Mg]$ in actinolite/diopside is 0.4.

7. A) Gen. Cat.--Skarns; replacement minerals

B) Joesten, R., 1974, Pseudomorphic replacement of melilite by idocrase in a zoned calc-silicate skarn, Christmas Mountains, Big Bend Region, Texas: *American Mineralogist*, v. 59, no. 7 and 8, p. 694-699.

C) Purpose: to describe the field, textural, and chemical relationship of this skarn.

Methods: petrography, electron microprobe, XRD.

Results: the presence of idocrase in the skarn is not related to the primary compositional zonation developed during diffusional growth of the skarn, but is the result of a lower temperature, hydrothermal replacement of melilite.

8. A) Gen. Cat.--skarn deposits

B) Skaarup, P., 1974, Strata-bound scheelite mineralization in skarns and gneisses from the Bindal area, Northern Norway: *Mineralium Deposita*, v. 9, no. 4, p. 299-308.

C) Purpose: to provide an account of these scheelite-bearing rocks in their regional environment.

Methods: chemical analyses (spectrographic whole rock analyses)

Results: Scheelite is present either in mobilized quartz veins or in skarnitized hornblende-biotite gneiss where limestone was in contact with these rocks. An exhalative-sedimentary origin of the mineralization is proposed, on account of the strata-bound character and the lack of any direct relationship to the plutonic rocks of the Bindal massif.

9 . A) Gen. Cat.--Skarns, mineralogic zoning

B) Shay, K., 1975, Mineralogical zoning in a scapolite-bearing skarn body on San Gorgonio Mountain, California: American Mineralogist, v. 60, no. 9 and 10, p. 785-797.

C) Purpose: to describe the geology and to chronicle the geological history of a small group of skarns on Mt. San Gorgonio.

Methods: geologic mapping, chemical analysis (XRF), XRD, petrography, electron microprobe.

Results : genesis of the skarns involved three steps: 1) regional metamorphism, 2) intrusion of quartz monzonite, and 3) infiltration of fluids.

10 . A) Gen. Cat.--Skarn deposits, Cu-Zn-Pb

B) Shimazaki, H., 1975, The ratios of Cu/Zn-Pb of pyrometasomatic deposits in Japan and their genetical implications: *Economic Geology*, v. 70, no. 4, p. 717-724.

C) Purpose: to present the ratios of Cu/Zn-Pb obtained from production figures together with the nature of related igneous rocks and their genetical relationships.

Methods: literature review (both published and unpublished)

Results: relatively Cu-rich pyrometasomatic deposits tend to be associated with plutonic igneous activity, while Zn-Pb-rich ones are associated with hypabyssal to effusive activity.

11. A) Gen. Cat.--Skarn deposits, CO₂ pressure.

B) Shoji, T., 1975, Role of temperature and CO₂ pressure in the formation of skarn and its bearing on mineralization: Economic Geology, v. 70, no. 4, p. 739-749.

C) Purpose: to estimate the temperatures and CO₂ pressures favorable for the formation of ore-bearing skarns.

Methods: geologic mapping, thermodynamic analyses.

Results: the favorable condition of formation of ore-bearing skarns is presumed to be as follows: 1) temperature is generally below 400°C, 2) CO₂ pressure has upper and lower limits determined by the stability of grandite garnet and the instability of xonotlite, hydrogrossular, and others, respectively, and 3) availability of iron in the ore-forming fluids.

12. A) Gen. Cat.--skarns, scheelite-bearing

B) Collins, B. I., 1977, Formation of scheelite-bearing and scheelite-barren skarns at Lost Creek, Pioneer Mountains, Montana: Economic Geology, v. 72, no. 8, p. 1505-1523.

C) Purpose: to develop a petrogenetic theory to account for the differences between mineralized and barren skarns.

Methods: petrography, electron microprobe, petrography.

Results: an inference may be drawn and applied to other skarns. Since differences in physical appearance, petrography, and chemistry exist between the mineralized and barren skarns, it is inferred that these characteristics are a manifestation of metasomatic processes operating in relatively clean and contaminated host marbles.

13. A) Gen. Cat.--Skarns, Cu-bearing

B) Einaudi, M. T., 1977, Petrogenesis of the copper-bearing skarn at the Mason Valley Miner, Yerington District, Nevada: Economic Geology, v. 72, no. 5, p. 769-795.

C) Purpose: to supply data and discussion aimed at quantifying the zoning, paragenesis, and composition of silicates associated with copper-bearing skarns.

Methods: geologic mapping, petrography, XRD, electron microprobe, chemical analyses.

Results: the initial silication process, as represented by zoned veins at the marble contact, may be attributed to isothermal metasomatic diffusion of Ca, Mg, and Si, with X_{CO_2} decreasing toward the vein centers. The abrupt appearance of new minerals coincides with the attainment of appropriate chemical potential values through metasomatism, rather than the crossing of isobaric univariant $T-X_{CO_2}$ equilibria. Bulk composition gradients are extreme and are reflected in the rapid increase in iron content of tremolite and diopside over a few centimeters from vein envelope to center.

14. A) Gen. Cat.--Skarn deposits

B) Wada, H., 1978, Carbon isotopic study on graphite and carbonate in the Kamoka mining district, Gifu Prefecture, central Japan, in relation to the role of graphite in the pyrometasomatic ore deposition: Mineralium Deposita, v. 13, no. 2, p. 201-220.

C) Purpose: to discuss the relationship between the carbon isotopic composition of carbonate and the chemical compositions of fluid from which skarn ores were formed.

Methods: C and O isotopes.

Results: $\delta^{13}\text{C}$ values of graphite in the skarn and the ores are close to those of graphites in the crystalline limestone. Graphite in the skarn and ores is considered to be remains of graphite in the crystalline limestone which was replaced by the skarn and the ores. At the pyrometasomatic stage, the oxygen fugacity of fluid would control the carbon isotopic composition of the calcite precipitated.

15. A) Gen. Cat.--skarn deposits

B) Shimazaki, H., 1980, Characteristics of skarn deposits and related acid magmatism in Japan: Economic Geology, v. 75, no. 2, p. 173-183.

C) Purpose: to summarize some characteristic features of skarn deposits in Japan.

Methods: literature review.

Results: nature of hydrothermal solutions originating in shallow environments does not seem to correlate with the associated acid magmatism. This may be interpreted to mean that, in such shallow environments, solutions of magmatic water, meteoric water, and other fluids with various oxidation states have interacted in the formation of the skarn deposits.

16. A) Gen. Cat.--skarn deposits, geobarometry

B) Shimizu, M.; Shimazaki, 1981, Application of the sphalerite geobarometer to some skarn-type ore deposits: Mineralium Deposita, v. 16, no. 1, p. 45-50.

C) Purpose: to apply the sphalerite geobarometer to skarn deposits.

Methods: petrography, electron microprobe

Results: most of the Cu-Fe skarn deposits studied were formed under pressures of more than 1 kb, whereas Zn-Pb (-Cu-Fe) deposits tend to have formed in relatively shallow environments, namely under less than 1 kb. The sphalerite geobarometry is quite sensitive even at low pressure ranges, and it is applicable to the deposits formed under shallow conditions.

17. A) Gen. Cat.-- Skarn deposits

B) Newberry, R. J., 1982, Tungsten-bearing skarns of the Sierra Nevada. I.

The Pine Creek mine, California: Economic Geology, v. 77, no. 4, p. 823-844.

C) Purpose: to describe the geology and alteration of the Pine Creek mine.Methods: Geologic mapping, petrography, XRD, electron microprobe.

Results: patterns of ore deposition were intimately tied to original lithologies and alteration types. Initial scheelite deposition accompanied high-temperature metasomatism of marble but not of hornfels or quartz monzonite. In the early-formed skarn, scheelite is concentrated toward the marble replacement front and depleted away from the marble. Molybdenite is concentrated in quartz-rich masses near intrusive contacts and in quartz-garnet veins cutting across metasomatized hornfels.

18. A) Gen. Cat.--Skarn deposits

B) Shimazaki, H., 1982, The Sasano Hastingsite-bearing copper skarn deposit formed in aluminous sediment at the Yoshioka mine, Japan: *Economic Geology*, v. 77, no. 4, p. 868-876.

C) Purpose: to describe a copper skarn that has formed in aluminous sediments.

Methods: petrography, chemical analyses (wet chemistry), electron microprobe.

Results: mineral assemblage and chemical compositions suggest that the chemical potentials of CaO and FeO increased toward the center of the deposit and were the predominant control on the on the formation of these skarns. The formation of this deposit can be treated as calcium-iron metasomatism and regarded as a kind of skarn formation, in spite of the fact that the original rock is not carbonate.

19. A) Gen. Cat.—Skarns, magnetite

B) Rose, A. W.; Herrick, D. C.; Deines, P., 1985, An oxygen and sulfur isotope study of skarn type magnetite deposits of the Cornwall type, Southeastern Pennsylvania: Economic Geology, v. 80, n. 2, p.418-443.

C) Purpose: to investigate the genetic relationship between igneous rock and ore and the conditions of ore deposition.

Methods: O and S isotope studies.

Results: Magnetite, silicate, and carbonate minerals in the skarn type ore in all 20 deposits are calculated to have formed in fluids with $\delta^{18}\text{O}_{\text{H}_2\text{O}}$ of 13 to 16 per mil. The high $\delta^{18}\text{O}$ of the fluid is difficult to explain by conventional ideas on a magmatic origin for skarn-forming fluids. The diabase, which has a normal igneous $\delta^{18}\text{O}$ of 7.4 to 7.8 per mil, would have furnished fluids with $\delta^{18}\text{O}$ of 7 to 10 per mil and therefore cannot be the direct source of the ore fluids. Preferred explanation of the ^{18}O -rich skarn is that an ^{18}O - and ^{34}S -enriched ore solution was formed by heating and circulation of meteoric, connate, or possible magmatic waters in sedimentary rocks near the contact of the diabase.

1. A) Gen. Cat.--Clays, cation exchange

B) Burns, A. F.; White, J. L., 1967, A micro method for determination of cation exchange capacity of clays by infrared spectroscopy: American Mineralogist, v. 52, no. 7 and 8, p. 1250-1252.

C) Purpose: to present a technique which has applications in cation exchange capacity determinations and which obviates the necessity for chemical analyses and requires a very small amount of material.

Methods: infrared absorption spectrometry.

Results: the relative rapidity and ease of the method, coupled with the small samples necessary, should make it particularly attractive in applications where limited amounts of materials are available.

2. A) Gen. Cat.—Absorption; mass absorption coefficients

B) Reynolds, R. C., 1967, Estimation of mass absorption coefficients by Compton scattering: improvements and extensions of the method: *American Mineralogist*, v. 52, no. 9 and 10, p. 1493-1502.

C) Purpose: to describe methods which extend the usefulness of a previously published method (Reynolds, 1963) for determining the mass absorption coefficient (μ) by means of Compton scattering.

Methods: X-ray emission analyses, mathematical analyses.

Results: appropriate values for μ can be computed for regions on the long wavelength sides of major element absorption edges by the use of a series of simultaneous equations in terms of (1) the mass absorption coefficient at .9A, (2) the intensities of the $K\alpha$ lines of the matrix elements, (3) published data on the rate of change of μ , for each matrix element, with respect to the wavelength, and (4) the major element analysis of a standard.

3 . A) Gen. Cat.--Sorption studies

B) Couch, E. L.; Grim, R. E., Boron fixation by illites: Clays and Clay Minerals, v. 16, no. 3, p. 249-256, 1968.

C) Purpose: gain a better understanding of the mechanism of B fixation by illites.

Methods: colorimetry, XRD.

Results: irreversible uptake of B was increased by increasing B or salt concentration, temperature, or time of treatment. Fixation was primarily controlled by surface area, but also by the crystallinity, K-content, and/or amount of mixed layer material. The proposed mechanism of B fixation consists of rapid adsorption of $B(OH)^-$ followed by much slower diffusion of B into the illite structure.

4. A) Gen. Cat.--Sorption studies

B) Schultz, L. G., 1969, Lithium and potassium adsorption, dehydroxylation temperature and structural water content of aluminous smectites:
Clays and Clay Minerals, v. 17, no. 3, p. 115-149.

C) Purpose: evaluate the factors that control expansion and thermal characteristics of montmorillonite and beidellite.

Methods: XRD, differential thermal and thermal gravimetric analyses, wet chemical methods.

Results: the Greene-Kelly Li^+ test is effective in distinguishing between montmorillonites and beidellites. Re-expansion after K^+ saturation at 300°C depends on total net layer charge and not the location of the charge. The major factor controlling dehydroxylation temperature is the amount of structural (OH).

5 . A) Gen. Cat.--Sorption studies

B) Von Reichenbach, H. G.; Rich, C. I., 1969, Potassium release from muscovite as influenced by particle size: Clays and Clay Minerals, v. 17, no. 1, p. 23-29.

C) Purpose: examine the K-Ba-selectivity of different size fractions of muscovite.

Methods: AAS, XRD, photometry.

Results: completeness of exchange of K from muscovite by Ba²⁺ ions decreased with particle size below 20 microns. At 120°C, K-exchange was accompanied by loss of Si and the formation of boehmite in the finer fractions. High K retention in fine fraction may be due to a lack of bending of these small particles.

6. A) Gen. Cat.-Sorptions studies

- . B) Barshad, I.; Kishk, F. M., 1970, Factors affecting potassium fixation and cation exchange capacities of soil vermiculite clays: Clays and Clay Minerals, v. 18, no. 2, p. 127-137.

C) Purpose: examine controls on fixation and CEC of vermiculites.

Methods: flame photometry, XRD.

Results: fixation capacity was fairly high for wet samples but was greatly enhanced by drying. High fixation by vermiculite clays, as opposed to coarse grained vermiculites, is believed due to the dioctahedral nature of coarse grained vermiculites. Reduction of Fe^{3+} caused a decrease in fixation but an increase in CEC, although these effects were reversible.

7. A) Gen. Cat.--Sorption studies

- B) Le Roux, J.; Rich, C. I.,; Ribbe, P. H., 1970, Ion selectivity by weathered micas as determined by electron microprobe analysis: Clays and Clay Minerals, v. 18, no. 6, p. 333-338.

C) Purpose: examine controls on ion segregation.

Methods: microprobe, AAS.

Results: Rb is concentrated, by sorption, at particle and step edges, in cracks and in "wedge zones" at interlayer boundaries. The restricted exchange of interlayer Mg by the Rb-Sr solution is due to a closing of interlayer space at the edges by sorb Rb.

8. A) Gen. Cat.--Sorption studies

B) Sawhney, B. L., 1970, Potassium and cesium ion selectivity in relation to clay mineral structure: *Clays and Clay Minerals*, v. 18, no. 1, p. 47-52.

C) Purpose: understand relationship between mineral structure and selectivity for K and Cs ions.

Methods: wet chemical analyses.

Results: montmorillonite had the least selectivity for the two ions, while biotite and illite had the greatest selectivity, except at high K concentrations, when vermiculite had the highest selectivity. This is attributed to the greater layer charge density in vermiculites. Selectivity of micas is due to frayed edges.

9 . A) Gen. Cat.--Sorption studies

B) Ferrell, R. E., Jr.; Brooks, R. A., 1971, The selective adsorption of sodium by clay minerals in Lakes Pontchartrain and Maurepos, Louisiana: *Clays and Clay Minerals*, v. 19, no. 2, p. 75-81.

C) Purpose: examine sorption of Mg and Na under natural conditions.

Methods: AAS.

Results: although previous work suggests that Mg should be preferentially sorbed, analysis of these sediments indicate the selective sorption of Na at the expense of Mg. As water chlorinity increases, exchangeable Na increases and exchangeable Mg decreases. Further, smectite content of clays increases as water salinity increases, and exchange capacity increases.

10. A) Gen. Cat.-- Sorption studies

B) Kozak, L. M.; Huang, P. M., 1971, Adsorption of hydroxy-Al by certain phyllosilicates and its relation to K/Ca cation exchange selectivity: *Clays and Clay Minerals*, v. 19, no. 2, p. 95-102.

C) Purpose: compare adsorption of hydroxy-Al by micas, vermiculite, and montmorillonite.

Methods: AAS, AES.

Results: differences in sorption of hydroxy-Al among the phyllosilicates is apparently related to the expansivity and layer charge of the minerals, the ionic saturation and degree of K-depletion, the OH/Al ratio of the hydroxy-Al solution and the solution/clay ratio. CEC reduction was not necessarily proportional to the amount of Al adsorbed. The basicity of the solution (OH/Al ratio) controls the amount of hydroxy-Al adsorbed and effects the cation exchange selectivity of the phyllosilicates.

11. A) Gen. Cat.--Sorption Studies

B) Mitra, R. D.; Sindhu, P. S., 1971, Acid character of sauconite: increase in cation exchange capacity on aging in water and the role of Zn^{2+} and Al^{3+} ions: Clays and Clay Minerals, v. 19, no. 6, p. 391-397.

C) Purpose: determine cation exchange behavior of sauconite.

Methods: wet chemical methods, polarography.

Results: H^+ , Al^{3+} , and Zn^{2+} could be exchanged for cations on the surface of the sauconite. When the sauconite aged in water (up to 3 months), exchangeable H^+ and Al^{3+} were replaced by Zn, eventually resulting in a Zn-clay. This was accompanied by an increase in solution pH from 4.2 to 6.3; CEC also increased about 70%. This was due to hydrolysis of octahedral Al at edges, leaving a net negative charge.

12. A) Gen. Cat.--Sorptions studies or Behavior of trace elements in geomedial
- B) Gal, M.; Rich, C. I., 1972, Selectivity effect of cesium on clay size weathered mica; transmission electron microscopy studies: Clays and Clay Minerals, v. 20, no. 3, p. 175-179.
- C) Purpose: examine local concentrations of interlayer cations in mica-vermiculite.

Methods: AAS, TEM.

Results: Cs was adsorbed to the near exclusion of Mg when both were added to clays and micas as exchange ions for Ca. The presence of Cs, in addition to the other interlayer cations, K and Ca, caused bending and perhaps splitting of the mica-vermiculite layers. Cs was probably concentrated on edges of particles.

13. A) Gen. Cat.--Sorption studies

B) Sawhney, B. L., 1972, Selective sorption and fixation of cations by clay minerals: Clay and Clay Minerals, v. 20, no. 2, p. 93-100.

C) Purpose: summarize data on sorption by clay minerals.

Methods: literature review.

Results: despite an increased understanding of sorption and fixation mechanisms, some aspects remain unclear. The inability of Ca or Mg ions to expand interlayers of Cs-saturated vermiculite is not understood. The factors that impede progressive K extraction are not known, and the mechanism of interlayer collapse in vermiculite on K or Cs sorption has not been established.

14 . A) Gen. Cat.--Sorptions studies or Behavior of trace elements in geomedia

B) Fordham, A. W., 1973, The location of iron-55, strontium-85, and iodide-125 sorbed by kaolinite and dickite particles: Clays and Clay Minerals, v. 21, no. 3, p. 175-184.

C) Purpose: determine location of cations after sorption from salt solution or precipitation from solution in the presence of clay.

Methods: SEM, autoradiography

Results: the majority of the positive sites and the most reactive negative sites are located at the edges of clay particles. When intentionally precipitated onto dickite, iron (III) hydroxides were distributed evenly on clay surfaces, although precipitation was probably initiated at the particle edges.

15 . A) Gen. Cat.--Sorptions studies or Behavior of clays in geomedial

B) Kharaka, Y. K.; Berry, F. A. F., 1973, Simultaneous flow of water and solutes through geological membranes - I. Experimental investigation: *Geochimica et Cosmochimica Acta*, v. 37, no. 12, p. 2577-2603.

C) Purpose: analyze efficiency of clays and shales as semipermeable membranes.

Methods: AAS, XRF, chemical methods

Results: efficiencies increase as CEC increases and solution concentration decreases. Higher pressure and lower temperatures had a positive effect on retardation efficiency. General retardation sequence for cations:

$\text{Li} \prec \text{Na} \prec \text{NH}_3 \prec \text{K} \prec \text{Rb} \prec \text{Cs}$ (monovalent)

$\text{Mg} \prec \text{Ca} \prec \text{Sr} \prec \text{Ba}$ (divalent)

General retardation sequence for anions (at 70°C):

$\text{HCO}_3 \prec \text{I} \prec \text{B} \prec \text{SO}_4 \prec \text{Cl} \prec \text{Br}$

16. A) Gen. Cat.--Sorption studies

B) Ross, G. J.; Rich, C. I., 1973, Effect of particle thickness on potassium exchange from phlogopite: *Clays and Clay Minerals*, v. 21, no. 2, p. 77-81.

C) Purpose: test the hypothesis that particle thickness is a primary factor controlling K release in micas.

Methods: AAS, wet chemical techniques.

Results: K selectivity of the fine fraction (0.2 - 2 micrometers) was higher than that of the coarse (54 - 75 micrometers) fraction. However, thickness made no difference, as practically 100% of the total K was exchanged from both thick and thin particles.

17. A) Gen. Cat.--Sorption studies

B) Ross, G. J.; Rich, C. I., 1973, Effect of particle size on potassium sorption by potassium-depleted phlogopite: *Clays and Clay Minerals*, v. 21, no. 2, p. 83-87.

C) Purpose: ascertain effects of particle size on rate and extent of K sorption.

Methods: XRD, AAS, electron microscopy.

Results: K sorption increased sharply with increasing particle size. This is explained by the greater amount of energy needed to initiate layer collapse (thus preventing sorption) in large particles than in small ones.

18. A) Gen. Cat.--Sorption studies

B) Steger, H. F., 1973, On the mechanism of the adsorption of trace copper by bentonite : Clays and Clay Minerals, v. 21, no. 6, p. 429-436.

C) Purpose: apply modified forms of the Boyd equation to obtain a better comprehension of the adsorption mechanism of Cu on bentonite.

Methods: XRD, AAS, wet chemical methods.

Results: protons, cupric ion, and mono (hydroxy) cupric complex were found to be the adsorbed species. There are two types of sites, of which are lattice hydroxyl groups located at crystal defects and edges. The remainder are related to adsorbed organic matter and are responsible for adsorption of Cu at low concentrations at $\text{pH} < 5.4$.

19. A) Gen. Cat.--Sorptions studies

B) Barker, C.; Torkelson, B. E., 1975, Gas adsorption on crushed quartz and basalt: *Geochimica et Cosmochimica Acta*, v. 39, no. 2, p. 212-218.

C) Purpose: document the adsorption of water, CO₂, CO, and CH₄ on crushed quartz and basalt.

Methods: mass spectrometry.

Results: newly broken surfaces are most efficient sorbers of the gases.

Overall, quartz was superior to basalt in sorption effectiveness. Quantity adsorbed for each gas showed the following trend: H₂O > CO₂ > CO ≥ CH₄.

20. A) Gen. Cat.--Sorption studies

B) Besson, G.; Estrade, H.; Gatineau, L.; Tchoubar, C.; Mering, J., 1975,

A kinetic survey of the cation exchange and of the oxidation of a vermiculite: *Clays and Clay Minerals*, v. 23, no. 4, p. 318-322.

C) Purpose: study kinetics of cation exchange in vermiculite.

Methods: gamma counting, electron paramagnetic resonance.

Results: during oxidation, the proportion of Fe which remains in the octahedral layer depends on the oxidizing agent. During weak oxidation, Fe remains in octahedral layers and the exchange capacity of the vermiculite decreases. Extraction of Fe during reaction with oxidizing waters does not change the exchange capacity of vermiculite.

21 . A) Gen. Cat.--Sorption studies

B) Das Kanungo, J. L., 1975, A study on the cation exchange of $[\text{Co}(\text{NH}_3)_6]^{3+}$ from $\text{H-Co}(\text{NH}_3)_6$ vermiculite by inorganic and quaternary ammonium ions: Clays and Clay Minerals, v. 23., no. 5, p. 361-364.

C) Purpose: study cation exchange behavior of hexamine cobalt on vermiculite.

Methods: wet-chemical methods, colorimetry.

Results: the distribution and selectivity coefficients of the desorbing monovalent ions increase in the order: $\text{Li} < \text{Na} < \text{NH}_4 < \text{K} < \text{Rb} < \text{H} < \text{Cs}$, and $\text{Ca} < \text{Mg}$ for divalent ions.

22. A) Gen. Cat.--Sorpton studies or Behavior of clay minerals in geomedia
- B) Maynard, J.B., 1975, Kinetics of silica sorption by kaolinite with application to seawater chemistry: American Journal of Science, v. 275, no. 9, p. 1028-1048.
- C) Purpose: examine the influence of detrital material on seawater chemistry.
- Methods: AAS, wet chemical analyses.
- Results: Data indicate a Z-stage reaction: 1) rapid sorption of H_4SiO_4 , initially, followed by 2) slower sorption that follows parabolic kinetics. Stage 2 is postulated as a seawater buffer mechanism, but the rate is too slow for the oceans to equilibrate with detrital phases.

23. A) Gen. Cat.--Sorption studies

B) Peigneur, P.; Maes, A.; Cremers, A., 1975, Heterogeneity of charge density distribution in montmorillonite as inferred from cobalt adsorption:

Clays and Clay Minerals, v. 23, no. 1, p. 71-75.

C) Purpose: analyze the adsorption behavior of cobalt ions in Na-montmorillonite.

Methods: XRD, wet chemical methods, scintillation spectrometry.

Results: differences in ion exchange behavior of clays towards divalent cations is due to varying contributions from regions with different charge densities. One region is associated with the constant charge fraction of the ion capacity; its exchange behavior is pH independent at low pH's (<math>pH < 4</math>). The second region is located at the edges of crystals, is identified with broken bonds, and its charge density is strongly pH dependent.

24. A) Gen. Cat.--Sorption studies

B) McBride, M. B., 1976, Origin and position of exchange sites in kaolinite:

an ESR study: Clays and Clay Minerals, v. 24, no. 2, p. 88-92.

C) Purpose: elucidate the properties of exchange sites on kaolinite.

Methods: AAS, XRD, ESR, wet chemical methods.

Results: divalent cations sorbed onto kaolinite are about 11-12 Å apart and planar $\text{Cu}(\text{H}_2\text{O})_4^{2+}$ ions are oriented parallel to the surfaces. Data suggest a high degree of mobility of Cu^{2+} and Mn^{2+} on kaolinite. Edge sites are apparently unimportant in ion exchange at lower pH's. Most exchange sites arise from ionic substitutions or mineral impurities in phyllosilicates.

25. A) Gen. Cat.--Sorption studies

B) McBride, M., 1976, Hydration structure of exchangeable Cu^{2+} in vermiculite and smectite: Clays and Clay Minerals, v. 24, no. 4, p. 211-212.

C) Purpose: compare published ESR data of exchangeable Cu^{2+} with data obtained on Cu^{2+} -doped vermiculite.

Methods: ESR, XRD.

Results: Cu^{2+} adsorbed on vermiculite resembles aqueous Cu^{2+} more than Cu^{2+} adsorbed on smectite does. This appears to be due to the weak ability of surface oxygens of smectite to hydrogen bond, thus hydrated Cu^{2+} can bond only weakly to smectite.

26. A) Gen. Cat.--Sorption studies or Behavior of trace elements in geomedial
- B) Yariv, S.; Shoval, S., 1976, Interaction between alkali-halides and halloysite: I.R. study of the interaction between alkali-halides and hydrated halloysite: *Clays and Clay Minerals*, v. 24, no. 5, p. 253-261.
- C) Purpose: examine why interaction of halloysite with salts of K^+ , NH_4^+ , Rb^+ and Cs^+ results in reversible lattice expansion.
- Methods: IR spectroscopy.
- Results: data indicate formation of complexes of halloysite with KCl, KBr, RbCl, CsCl. Water was essential in complex formation. The amount of complex formed depended, in part, on the salt used. Complex formation requires that the cation be a weak electron acceptor.

27. A) Gen. Cat.--Sorption studies

B) Koppelman, M. H.; Dillard, J. G., 1977, A study of the adsorption of Ni(II) and Cu(II) by clay minerals: *Clays and Clay Minerals*, v. 25, no. 6, p. 457-462.

C) Purpose: examine untreated chlorite and chlorite after sorption of Ni^{2+} and Cu^{2+} .

Methods: XPS, AAS.

Results: the quantity of Ni^{2+} at pH = 6 and Cu^{2+} at pH = 5 adsorbed varies in the manner chlorite > illite > kaolinite. Data indicate that Ni^{2+} is probably bound as the aqua ion, while Cu^{2+} may be adsorbed as $\text{Cu}(\text{OH})^+$.

28. A) Gen. Cat.--Sorption studies

B) McBride, M.B., 1977, Adsorbed molecules on solvated layer silicates:

surface mobility and orientation from ESR studies: Clays and Clay Minerals, v. 25, no. 1, p. 6-13.

C) Purpose: develop a more complete knowledge of adsorption processes.

Methods: ESR spectroscopy, XRD.

Results: surface-molecule interaction is modified by the solvent present and the nature of the surface. Adsorbed molecules exhibit reduced diffusion constants and non-random tumbling at the liquid-surface interface. Tumbling occurs on clays with a weak attraction for water molecules (i.e., smectites).

29. A) Gen. Cat.--Sorption studies

B) McBride, M. B., 1977, Exchangeable cation and solvent effects upon the interlamellar environment of smectites: ESR spin probe studies: Clays and Clay Minerals, v. 25, no. 3, p. 205-210.

C) Purpose: examine the effect of an adsorbed cation on the sorbant surface.

Methods: XRD, ESR spectroscopy.

Results: mobility and orientation of probe molecules were greatly affected by the solvent, and to a lesser extent by adsorbed cations. Most effects could be interpreted in terms of basal spacings of the hectorite. Adsorbed probes were much less mobile than those in solution in all cases.

30.A) Gen. Cat.--Sorption studies

B) Neal, C., 1977, The determination of adsorbed Na, K, Mg, and Ca on sediments containing CaCO_3 and MgCO_3 : Clays and Clay Minerals, v. 25, no. 4, p. 253-258.

C) Purpose: describe a new method for determining exchangeable cations on calcareous sediments.

Methods: AAS.

Results: the amount of cation exchanged on 2 clays was found to vary with the proportions of clay mineral in the mixtures. The method described has the advantages of preventing carbonate dissolution or precipitation, and allowing determinations to be made using a single cation leach and its blank.

31. A) Gen. Cat.--Sorption studies

B) Ferrell, R. E., Jr.; Price, C. A., 1978, An experimental study of cadmium ion exchangeability: *Clays and Clay Minerals*, v. 26, no. 1, p. 41-44.

C) Purpose: examine the influence of ion exchange extraction techniques on the exchangeability of cadmium.

Methods: XRD, AAS.

Results: the exchange solutions removed increasing amounts of Cd in the following order: N NaNO_3 ; N NaO acetate; N NH_4O acetate; N CaCl_2 ; 2N CaCl_2 . Data indicate that octavite (Cd carbonate) precipitated in acetate solutions; thus removal figures were erroneously high. Cd values obtained in chloride solutions were also too high, due to dissolution of solid phases, lack of pH buffering, and possible formation of a complex hydroxyl chloride salt. NaNO_3 solutions best model Cd exchange in sediment.

32. A) Gen. Cat.--Sorption studies

B) McBride, M. B., 1978, Copper (II) interactions with kaolinite: factors controlling adsorption: Clays and Clay Minerals, v. 26, no. 2, p. 101-106.

C) Purpose: measure Cu^{2+} adsorption on kaolinite at varying solution pH's and ionic strengths.

Methods: flame photometry, wet chemical methods.

Results: sodium exchanged kaolinite had a strong affinity for Cu^{2+} , while natural kaolinite had only a weak affinity. Cu^{2+} adsorption generates protons, as a result of exchange. At higher Cu^{2+} concentration, hydrolysis may precede adsorption.

33. A) Gen. Cat.--Sorption studies

B) Veith, J. A., 1978, Selectivity and adsorption capacity of smectite and vermiculite for aluminum of varying basicity: *Clays and Clay Minerals*, v. 26, no. 1, p. 45-50.

C) Purpose: investigate the effects of varying degrees of basicity on Al sorption.

Methods: XRD, AAS.

Results: the average basicity of Al adsorbed differed greatly from the basicity of the Al added to solution. Al adsorbed by smectite was always more basic than the average in solution; vermiculite showed the opposite trend. Smectite adsorbed considerably more Al than vermiculite.

34. A) Gen. Cat.--Sorption studies

B) Adams, J. M.; Evans, S., 1979, Exchange and selective surface uptake of cations by layered silicates using X-ray photoelectron spectroscopy (XPS): Clays and Clay Minerals, v. 27, no. 4, p. 248-252.

C) Purpose: assess utility of XPS in CEC determinations.

Methods: XPS.

Results: CEC's obtained by XPS are close to those derived by wet chemical methods on Na- and Ca- clays. However, apparent CEC's obtained following K-, Pb-, or Ba- exchange are about 50% greater than those analyzed chemically. It is concluded that the excess detected by XPS is due to a concentration of cations at the surfaces of the clay particles.

35. A) Gen. Cat.--Sorption studies

B) Chu, C. H.; Johnson, L. J., 1979, Cation-exchange behavior of clays and synthetic aluminosilicate gels: *Clays and Clay Minerals*, v. 27, no. 2, p. 87-90.

C) Purpose: compare CEC values obtained by methylene blue (MB) adsorption and K displacement by NH_4 (K/NH_4) with values obtained by Ca displacement by Mg (Ca/Mg).

Methods: XRD, wet chemical methods.

Results: CEC values determined by MB and K/NH_4 methods correlate closely in five soil clays, but differ greatly in two clays with large amorphous matter contents. The MB method provided a more precise distinction between vermiculite and montmorillonite than the K/NH_4 method. Aluminosilicate gels showed CEC determined by $\text{K}/\text{NH}_4 \approx \text{Ca}/\text{Mg} \approx \text{MB}$, but no relation to amorphous material was found.

36. A) Gen. Cat.--Adsorption

B) Farrah, H.; Pickering, W. F., 1979, pH effects in the adsorption of heavy metal ions by clays: *Chemical Geology*, v. 25, no. 4, p. 317-326.

C) Purpose: to summarize the results of a study on the uptake of hydrogen or hydroxyl ions by clay suspensions, and the influence of this on metal ion uptake.

Methods: adsorption studies, pH measurements.

Results: the amount of hydroxonium or hydroxyl ion sorbed by the sodium form of clays (kaolin, illite, or montmorillonite) has been found to increase in proportion with the amount added. The adsorptive capacities, and bonding strengths (as evaluated from Langmuir isotherm plots) varied with clay type and nature of the adsorbing species (values for OH^- being greater than for H^+).

37.A) Gen. Cat.--Sorption studies

B) Inoue, A.; Minato, H., 1979, Ca-K exchange reaction and interstratification in montmorillonite: *Clays and Clay Minerals*, v. 27, no. 6, p. 393-401.

C) Purpose: study formation of illite from montmorillonite.

Methods: XRD, AAS, AES.

Results: changes of the standard free energies for the exchange from K- to Ca-montmorillonite are -53, -270, and -393 cal/eq at 35^o, 50^o, and 90^oC, respectively. Changes of the standard enthalpy and entropy were found to be 1.7 kcal/eq and 5.6 cal/eq/degree, respectively, at 35^oC. Hydration entropy of cations determined sign of the change in standard free energy. The mixing model of Ca-K-montmorillonite approximates that of a regular solution.

38. A) Gen. Cat.--Sorption studies

B) Keren, R., 1979, The effect of hydroxy-aluminum precipitation on the exchange properties of montmorillonite: *Clays and Clay Minerals*, v. 27, no. 4, p. 303-304.

C) Purpose: determine the effect of hydroxy-Al interlayers on the selectivity coefficient of Na-Ca exchange of montmorillonite.

Methods: gamma counting.

Results: the clays strongly preferred Ca to Na. This was especially pronounced for clays with hydroxy-Al interlayers. Selectivity of the pure clay varied with Na content, while selectivity of the clay with hydroxy-Al interlayers only varied slightly.

39. A) Gen. Cat.--Sorption studies

B) Maes, A.; Stul, M. S.; Cremers, A., 1979, Layer charge - cation-exchange capacity relationships in montmorillonite: *Clays and Clay Minerals*, v. 27, no. 5, p. 387-392.

C) Purpose: examine cation-exchange on isostructural samples of decreasing layer charge.

Methods: wet chemical analysis (alkylammonium method)

Results: the charge density among different classes of a series of reduced charge montmorillonites is heterogeneous. Charge reduction proceeds inhomogeneously. Up to 20% differences in charge density can be accounted for by alkyl chains attached to edges of the clays. Na^+ CEC increases as charge density increases.

40. A) Gen. Cat.--Sorption studies

B) Mattigod, S. V.; Gibali, A. S.; Page, A. L., 1979, Effect of the ionic strength and ion pair formation on the adsorption of nickel by kaolinite: Clays and Clay Minerals, v. 27, no. 6, p. 411-416.

C) Purpose: clarify adsorption behavior of Ni on kaolinite.

Methods: AAS.

Results: increasing ionic strength resulted in decreased Ni adsorption. Ni adsorption was greatest when NO_3 was the dominant anion in solution. The standard free energy of adsorption of Ni^{2+} on kaolinite was computed to be -27 kJ/mol.

41. A) Gen. Cat.--Sorption studies

B) McBride, M. B., 1979, Mobility and reactions of VO^{2+} on hydrated smectite surfaces: *Clays and Clay Minerals*, v. 27, no. 2, p. 91-96.

C) Purpose: describe the mobility of VO^{2+} on smectite under different conditions.

Methods: ESR spectra.

Results: hydrolysis of VO^{2+} was promoted at low levels of adsorption. An approximately 50% reduction in rotational mobility of VO^{2+} relative to solution was indicated. Loss in mobility occurred with reduction of inter-lamellar spacing until $\text{VO}(\text{H}_2\text{O})_5^{2+}$ ions became aligned with the V=O bond axis normal to the plane of the clay platelets.

42 . A) Gen. Cat.--Sorption studies

B) McBride, M. B., 1979, Cationic spin probes on hectorite surfaces: demixing and mobility as a function of adsorption level: Clays and Clay Minerals, v. 27, no. 2, p. 97-104.

C) Purpose: observe effects of molecular cation concentration on the clay surface upon mobility and orientation of sorbed species.

Methods: ESR spectra.

Results: the organic cation TEMPAMINE⁺ tends to concentrate in certain interlayers of the aqueous hectorite suspensions even when occupying only a small fraction of the cation-exchange sites. Average mobility increases at higher adsorption levels due to the shift of the equilibrium in favor of the solution state.

43 . A) Gen. Cat.--Sorption studies

B) McBride, M. B., 1979, An interpretation of cation selectivity variations in M^+-M^+ exchange on clays: Clays and Clay Minerals, v. 27, no. 6, p. 417-422.

C) Purpose: investigate the variability of the selectivity of montmorillonite for K^+ relative to Na^+ .

Methods: thermodynamic analysis.

Results: montmorillonite's preference for K^+ relative to Na^+ , as increasing amounts of K^+ are adsorbed, decreases; this is the general rule for the exchange of strongly hydrating ions by weakly hydrating ions. Variability in selectivity is related to surface entropy, which itself is a function of chemical properties of the exchanging ions and the nature of the adsorption sites. Use of the mass action expression to describe exchange may be restricted to systems where both ions have solution-like mobility at the exchange surface.

44. A) Gen. Cat.--Sorption studies

B) Sherry, H. S., 1979, Ion-exchange properties of the natural zeolite erionite:

Clays and Clay Minerals, v. 27, no. 3, p. 231-237.

C) Purpose: compare ion-exchange properties of the erionite and offretite frameworks.

Methods: XRD, beta and gamma counting.

Results: the selectivity series of erionite is $Rb \succ Cs \cong K \succ Ba \succ Sr \succ Ca \succ Na \succ Li$.

Replacement of 2 Na^+ ions in the erionite unit cell was found to be extremely difficult, probably because this would result in a non-uniform divalent cation population. Similarly, 2 K^+ ions per unit cell could not be replaced by ion exchange methods, most likely due to their incorporation in cancrinite cages.

45. A) Gen. Cat.--Sorption studies

B) Simonot-Grange, M. H., 1979, Thermodynamic and structural features of water sorption in zeolites: *Clays and Clay Minerals*, v. 27, no. 6, p. 423-428.

C) Purpose: acquire a precise knowledge of the zeolite structure.

Methods: XRD, thermal gravimetric and differential thermal analyses.

Results: water adsorption in zeolites is a function of temperature and pressure. Desorption may be of 3 types: 1) little or no lattice change; 2) reversible lattice change; 3) irreversible lattice change. Sorption is closely related to the total volume available for the adsorbate in the zeolite framework. Shapes of water sorption curves correspond to structural changes occurring during dehydration or rehydration of the zeolite.

46. A) Gen. Cat.--Sorption studies or Behavior of trace elements in geomedial
- B) Sposito, G.; Mattigod, S. V., 1979, Ideal behavior in Na⁺-trace metal cation exchange on Camp Berteau montmorillonite: Clays and Clay Minerals, v. 27, no. 2, p. 125-128.
- C) Purpose: examine ideality in cation exchange.
- Methods: thermodynamic analysis
- Results: exchanger phases exhibit ideal behavior if the Vanselow selectivity coefficient is independent of the exchanger composition and the stoichiometric cation-exchange reaction is reversible. Application of this criterion to Na⁺-trace metal exchange on Camp Berteau montmorillonite indicates that the exchanger phase behaves as an ideal mixture.

47. A) Gen. Cat.--Adsorption

B) Brûlé, D. G.; Brown, J.R.; Bancroft, G. M.; Fyfe, W. S., 1980,
Cation adsorption by hydrous manganese dioxide: a semi-
quantitative x-ray photoelectron spectroscopic (ESCA) study:
Chemical Geology, v. 28, no. 3/4, p. 331-339.

C) Purpose: to describe a new method for obtaining smooth surfaces of
hydrous manganese dioxide, and to report preliminary Ba^{2+} , Ni^{2+} ,
and La^{3+} adsorption results on these surfaces using the ESCA
technique.

Methods: x-ray photoelectron spectroscopy (or ESCA)

Results: plots of metal uptake on the surface vs. time for various
metal concentrations are characteristic of sorption processes. The
selectivity sequence determined from this study is $Ba^{2+} \gg Ni^{2+} \gtrsim La^{3+}$.

48. A) Gen. Cat.--Sorption studies

B) Eberl, D. D., 1980, Alkali-cation selectivity and fixation by clay minerals:

Clays and Clay Minerals, v. 28, no. 3, p. 161-172.

C) Purpose: examine controls on K_e for an exchanging ion pair.

Methods: thermodynamic analysis.

Results: the exchange free energy (ΔG°_{ex}) for smectites in a high state of hydration can be calculated using only the equivalent anionic radius (r_a) of the cations undergoing exchange. The layer charge necessary for cation fixation can also be calculated from r_a . The theory can be applied qualitatively to understand the high selectivity of illite for Cs^+ , the fixation of K^+ rather than Na^+ in shales during diagenesis, and cation segregation in smectite.

49. A) Gen. Cat.--Sorption studies

B) Egozy, Y., 1980, Adsorption of cadmium and cobalt on montmorillonite as a function of solution composition: Clays and Clay Minerals, v. 28, no.4, p. 311-318.

C) Purpose: examine adsorption of Cd^{2+} , Co^{2+} , and Sr^{2+} on montmorillonite from solutions with a range of salt contents.

Methods: gamma counting.

Results: distribution coefficients for Co and Cd in noncomplexing media decreased with increasing salt content (from about 500 liters/kg in 0.01 M Na^+ to around 10 liters/kg in 1 M Na^+ at pH=5) but to a lesser extent than Sr. Adsorbability of Co and Cd varied with pH, especially at high ionic strength, while that of Sr did not. Data suggest that 2 types of sites participate in the adsorption of Cd and Co. High concentrations of Cl inhibited Cd adsorption by chloride complex formation.

50. A) Gen. Cat.--Adsorption

B) Farrah, H.; Hatton, D.; Pickering, W. F., 1980, The affinity of metal ions for clay surfaces: *Chemical Geology*, v. 28, no. 1/2, p. 55-68.

C) Purpose: to re-examine the effect of concentration and competing divalent cations on the uptake of metal ions.

Methods: adsorption studies.

Results: an investigation of the adsorption, at 25°C, and pH = 5.0, of Pb, Cu, Zn, Cd, Mg, and Ca ions by Na⁺ - form kaolin, illite and montmorillonite, has shown that the effect of concentration can be described by a Langmuir isotherm. The derived values for the constant k were all of the order 10⁵ L mol⁻¹ with the pre-power terms varying between cations within the range of 1-5 (kaolin and illite) or 3-10 (montmorillonite).

51. A) Gen. Cat.--Sorptions studies or Behavior of trace elements in geomedial

B) Komarneni, S.; Roy, D. M., 1980, Hydrothermal effects on cesium sorption and fixation by clay minerals and shales: *Clays and Clay Minerals*, v. 28, no. 2, p. 142-148.

C) Purpose: determine effects of hydrothermal treatment on Cs sorption by clay minerals.

Methods: AA, XRD.

Results: hydrothermal heating lead to a decrease in the sorptive capacities of clay minerals and shales. The effect was least on poorly crystallized illites, some of which showed a slight increase in sorption. Hydrothermal heating of Cs-sorbed or Cs-saturated samples increased Cs-fixation as a result of layer collapse.

52. A) Gen. Cat.--Adsorption studies

B) Koppelman, M. H.; Emerson, A. B.; Dillard, J. G., 1980, Adsorbed Cr(III)

on chlorite, illite, and kaolinite: an X-ray photoelectron spectroscopic study: Clays and Clay Minerals, v. 28, no. 2, p. 119-124.

C) Purpose: examine mechanisms of Cr sorption.

Methods: AAS, spectrophotometry, XPS.

Results: in all cases, the amount of Cr adsorbed was between 3.1×10^{-5} and 16.6×10^{-5} mole Cr/g. Adsorption increased with pH due to decreased site competition by H^+ . Below pH = 4, Cr is probably adsorbed as a Cr(III) aqua ion.

53. A) Gen. Cat.--Sorptions studies

B) Lim, C. H.; Jackson, M. L.; Koons, R. D.; Helmke, P. A., 1980, Kaolins: sources of differences in cation-exchange capacities and cesium retention: Clays and Clay Minerals, v. 28, no. 3, p. 223-229.

C) Purpose: identify sources of variation of CEC in kaolins.

Methods: XRD, AAS.

Results: the Ca and Cs exchange capacities of seven kaolins varied from 2.67 to 8.17 and 3.29 to 8.77 meq/100 g, respectively. Data indicate that expandable 2 : 1 clays, particularly smectite, were responsible for variation in Ca CEC. Cs-retention capacity (0.19-1.14 meq/100 g) was closely related to vermiculite content.

54. A) Gen. Cat.--Sorption studies

B) Wada, K.; Kakuto, Y., 1980, Selective adsorption of zinc on halloysite:

Clays and Clay Minerals, v. 28, no. 5, p. 321-327.

C) Purpose: evaluate adsorption capacities of halloysite for Zn.

Methods: XRD, AAS.

Results: all Zn adsorption occurred at cation exchange sites, and 0.77 to 36.0 meq Zn/100 g clay (9 to 83% of the CEC) was adsorbed with a high selectivity relative to Ca. High values were associated with spherical and filmy halloysites; low values with tubular halloysites. High selectivity sites for Zn correlated with a large proportion of high affinity sites for H^+ . Selective Zn adsorption decreased with decreasing pH.

55 . A) Gen. Cat.--Adsorption

B) Borovec, Z., 1981, The adsorption of uranyl species by fine clay:

Chemical Geology, v. 32, no. 1/2, p. 45-58.

C) Purpose: to ascertain the distribution of UO_2^{2+} species between the solution (pure water) and the dispersed clay particles in suspension.

Methods: XRD, differential thermal analysis, chemical analyses (XRF, infrared spectroscopy), scanning electron microscopes, transmission electron microscopes, adsorption studies.

Results: the uptake of UO_2^{2+} and its hydroxo complexes has been determined at 20°C and pH 6.0 for fine grained illite, kaolinite, and montmorillonite. Uptake from solutions of U(VI) species at concentrations greater than $10^{-4} \text{ mol L}^{-1}$ may be formally expressed by the Langmuir equation for adsorption, whereas the Freundlich equation applies at lower concentrations.

56. A) Gen. Cat.--Sorption studies or Behavior of trace elements in geomedia

B) Podosek, F. A.; Bernatowicz, T. J.; Kramer, F. E., 1981, Adsorption of xenon and krypton on shales: *Geochimica et Cosmochimica Acta*, v. 45, no. 12, p. 2401-2415.

C) Purpose: report adsorption data for Xe and Kr on rocks.

Methods: use of mass spectrometer as a partial pressure manometer.

Results: heats of adsorption range from 2-7 kcal/mol; Henry constants of the order of magnitude $1 \text{ cm}^3 \text{ STPg}^{-1} \text{ atm}^{-1}$ at 0 to 25°C are calculated. It does not seem that adsorption can account for the atmospheric Xe deficiency (relative to meteorites). Equilibrium adsorption takes place very slowly and may account for experimental observations without invoking any other mechanisms.

57. A) Gen. Cat.--Adsorption studies

B) Shibue, Y., 1981, Cation-exchange reactions of siliceous and aluminous phillipsites: Clays and Clay Minerals, v. 29, no. 5, p. 397-402.

C) Purpose: compare exchange properties of phillipsites with various Si/Al ratios.

Methods: wet chemical methods, AAS, flame photometry, spectrophotometry.

Results: the thermodynamic affinity sequences were $K \succ Na \succ Ca$ in both phillipsites. Selectivity of K in competition with Na, and Na in competition with Ca was more pronounced at lower temperatures. The siliceous phillipsite preferred K to Na, and Na to Ca, more strongly than the aluminous phillipsite.

58. A) Gen. Cat.--Sorption studies

B) Sung, W.; Morgan, J. J., 1981, Oxidative removal of Mn(II) from solution catalyzed by the δ -FeOOH (lepidocrocite) surface: *Geochimica et Cosmochimica Acta*, v. 45, no. 12, p. 2377-2383.

C) Purpose: ascertain role of surface catalysis in Mn^{2+} oxidative removal.

Methods: spectrophotometry, chemical analyses.

Results: the rate law for Mn removal in a seawater system with $[Fe^{3+}] = 10^{-5} M$

is:

$$-\frac{d[Mn^{2+}]}{dt} = 2.0 \times 10^{-2} d^{-1} [Mn^{2+}]$$

The corresponding half life is 35 days. The presence of millimolar levels of δ -FeOOH can significantly reduce the half-life of Mn^{2+} .

59. A) Gen. Cat.--Sorption studies or Behavior of actinides in geomeia
- B) Tsunashima, A.; Brindley, G. W.; Bastovanov, M., 1981, Adsorption by montmorillonite; compositions and properties of uranyl montmorillonites: Clays and Clay Minerals, v. 29, no. 1, p. 10-16.

C) Purpose: examine the adsorption of U by montmorillonite under various conditions.

Methods: XRD, fluorimetry, AAS.

Results: montmorillonite sorbed uranyl ions more efficiently than Na^+ or K^+ , but less than Mg^{2+} , Ca^{2+} , or Ba^{2+} . A fully exchanged uranyl montmorillonite was prepared and the resulting interlayer composition was $(\text{UO}_2)_{0.19}(\text{H}_2\text{O})_{1.15}$, which corresponds to the hexohydrate ion, $[(\text{UO}_2) \cdot 6\text{H}_2\text{O}]$.

60 . A) Gen. Cat.--sorption, clay minerals

B) Wold, J.; Pickering, W. F., 1981, Influence of electrolytes on metal ion sorption by clays: *Chemical Geology*, v. 33, no. 1/2, p. 91-99.

C) Purpose: to study how the adsorption of anions by clays can affect metal-ion uptake.

Methods: Sorption studies

Results: Distribution of the metal ions between the phases tended to be controlled by precipitation when interaction with added anions yielded sparingly soluble products, e.g., in presence of PO_4^{3-} and $\text{P}_2\text{O}_7^{4-}$. Complex formation in alkaline media (e.g., with NaPO_3 or $\text{P}_2\text{O}_7^{4-}$) favored retention in the aqueous phase.

61 . A) Gen. Cat.--Sorpton, basalt

B) Ames, L. L.; McGarran, J. E.; Walker, B. A.; Salter, P. F., 1982,
Sorpton of uranium and cesium by Hanford basalts and associated
secondary smectite. Chemical Geology, v. 35, no. 3/4, p. 205-
225.

C) Purpose: to study the sorpton of U and Cs by Hanford basalts and
associated secondary smectite.

Methods: chemical analyses (XRF), sorpton studies.

Results: an increase in temperature caused a decrease in Cs sorpton
maxima on all solids from all groundwaters studied and an increase in
U sorpton maxima, especially from the higher-carbonate-content ground-
water. Sorpton energies were characteristic of ion exchange for both
Cs and U sorpton processes. Basalt U sorpton maxima were relatively
insignificant, but smectite U sorpton maxima surpassed Cs sorpton
at 60°C.

62. A) Gen. Cat.--Adsorption studies

B) Balistrieri, L. S.; Murray, J. W., 1982, The surface chemistry of goethite (α FeOOH) in major ion seawater: American Journal of Science, v. 281, no. 6, p. 788-806.

C) Purpose: quantify the scavenging ability of solid surfaces in natural waters.

Methods: XRD, AAS.

Results: about 1/3 of the surface sites on goethite are bound by H. Very few sites are ionized, and dominant complexes are with Mg and SO_4 . Use of a site binding model allows prediction of potentiometric adsorption data for goethite in simple and complex situations.

63. A) Gen. Cat.--Adsorption

B) Hein, J. R.; Koski, R. A.; Morgenson, L. A., 1982, Uranium and thorium enrichment in rocks from the base of DSDP Hole 465A, Hess Rise, central North Pacific: *Chemical Geology*, v. 36, no. 3/4, p. 237-251.

C) Purpose: to discuss the occurrence of U and Th in organic-rich calcareous rocks from the central North Pacific.

Methods: drill core studies, XRD, chemical analyses (XRF, neutron activation analyses, semi-quantitative emission spectroscopy)

Results: U was initially derived from seawater and concentrated by adsorption on terrigenous (humic) organic matter in limestone in a shallow marine environment. U and Th were probably concentrated further by low-temperature hydrothermal fluids emanating from the basaltic basement. To better understand the conditions limiting the migrating and concentration of U and Th, other rocks deposited during the ocean-wide Cretaceous anoxic events should be analyzed for these elements.

64. A) Gen. Cat.--Sorption studies

B) Miller, S. E.; Heath, G. R.; Gonzalez, R. D., 1982, Effects of temperature on the sorption of lanthanides by montmorillonite: Clays and Clay Minerals, v. 30, no. 2, p. 111-122.

C) Purpose: obtain a better understanding of the interaction between radioactive waste elements and clays.

Methods: polarography, XRD, IR.

Results: dehydration of montmorillonite between 100°C and 280°C caused lanthanide ions to diffuse into hexagonal rings of surface oxygen. Considerable ion fixation occurred at 20°C in both water and a 1:1 water : 95% ethanol mixture. Hydrolysis of Na-montmorillonite was not observed.

65. A) Gen. Cat.--Sorption

B) Torstenfelt, B.; Anderson, K.; Allard, B., 1982, Sorption of strontium and cesium on rocks and minerals. In: G. W. Bird and W. S. Fyfe (Editors), Geochemistry of Nuclear Waste Disposal: Chemical Geology, v. 36, no. 1/2, p. 123-137.

C) Purpose: to discuss the sorption of Sr and Cs on some geologic media representative of igneous rocks.

Methods: petrography, sorption studies, XRD, cation-exchange capacity measurements.

Results : the most important parameters influencing the sorption were the nuclide concentration, the groundwater composition and the mineral composition (e.g., presence of minerals with high cation-exchange capacity and/or high surface/mass ratio).

66. A) Gen. Cat.--Sorption

B) Vandergraaf, T. T.; Abry, D. R. M.; Davis, C. E., 1982, The use of autoradiography in determining the distribution of radionuclides sorbed on thin sections of plutonic rocks from the Canadian Shield. In : G. W. Bird and W. S. fye (Editors), Geochemistry of Radioactive Waste Disposal. Chemical Geology, v. 36, no. 1/2, p. 139-154.

C) Purpose: to use autoradiography to determine the distribution of radionuclides sorbed under oxic conditions onto rock thin sections representative of the four major types of plutons in the Canadian Shield.

Methods: petrography, autoradiography.

Results: sorption was found to be negligible on quartz and strongest on the mafic minerals- the pyroxenes, micas, hornblendes and opaques, and on alteration minerals - chlorite and sphene. Precipitation of Am and Pm was observed, indicating that, for actinides and rare earths, experimentally obtained static sorption coefficients may reflect precipitation as well as sorption and must be used with caution in modelling studies.

67. A) Gen. Cat.--Sorption studies or Behavior of actinides in geomeia

B) Ames, L. L.; McGarrah, J. E.; Walker, B. A., 1983, Sorption of trace constituents from aqueous solutions onto secondary minerals. I. Uranium: Clays and Clay Minerals, v. 31, no. 5, p. 321-334.

C) Purpose: determine controls on U sorption.

Methods: NAA, AFS.

Results: silica gel effeciently sorbed uranyl carbonate anion complexes.

Materials with high CEC rapidly sorbed uranyl ions from 0.01M NaCl solution.

Increases in temperature generally decreased U sorption, except when U was present as carbonate complexes. Noncrystalline Fe-hydroxide sorbed U more effeciently than any secondary minerals.

68. A) Gen. Cat.--Sorption studies

B) Ames, L. L.; McGarrah, J. E.; Walker, B. A., 1983, Sorption of trace constituents from aqueous solutions onto secondary minerals: II.

Radium: Clays and Clay Minerals, v. 31, no. 5, p. 335-342.

C) Purpose: allow comparisons of sorption efficiencies of secondary minerals for Ra and U.

Methods: XRD, scintillation counting.

Results: clinoptilolite, illite, and nontronite were the most efficient Ra sorbents; opal and silica gel were the least efficient. Generally, Ra sorption was much greater than U sorption under similar conditions.

69. A) Gen. Cat.--Sorptions studies or Behavior of trace elements in geomedial
- B) Ames, L. L.; McGarrah, J. E.; Walker, B. A., 1983, Sorption of uranium and radium by biotite, muscovite, and phlogopite: Clays and Clay Minerals, v. 31, no. 5, p. 343-351.
- C) Purpose: obtain rigorous, comparative data on the U and Ra-sorption ability of micas.
- Methods: XRD, SEM, scintillation counting.
- Results: sorption of both U and Ra on micas was adequately described by the Freundlich adsorption equation, at low U and Ra concentrations. Increasing concentration or temperature decreased distribution coefficients. In 0.01 M NaHCO₃ solutions, U is very effectively sorbed by muscovite but only poorly sorbed by the mafic micas.

70. A) Gen. Cat.—Radionuclide sorption on fracture filling minerals in a granitic pluton.

B) Kaminen, D. C.; et. al., 1983, Characteristics of radionuclide sorption on fracture-filling minerals in the Eye-Dashwa Lakes pluton, Atikokan, Ontario: Canadian Mineralogist, v. 21, p. 625-36.

C) Purpose: since fractures will play a part in transport of RAD waste, fracture filling minerals were studied as possible impede of radionuclide migration.

Methods: various radionuclides were sorbed on thin sections of sample rock. Distribution of sorbed radionuclides were determined by autoradiography.

Results: enhanced sorption by secondary minerals compared to primary was observed.

71. A) Gen. Cat.--Hydrothermal reactions or Sorption studies

B) Komarneni, S.; White, W. B., 1983, Hydrothermal reactions of strontium and transuranic simulator elements with clay minerals, zeolites, and shales: Clays and Clay Minerals, v. 31, no. 2, p. 113-121.

C) Purpose: determine extent and nature of reaction of Sr, La, Nd (the latter two simulating Am and Cs) with potential backfill materials.

Methods: XRD, AES, AAS.

Results: chlorite, illite, kaolinite, and montmorillonite removed up to 61.2% of added SrCl_2 and 98.5% of added $\text{Sr}(\text{OH})_2$ from solution, by ion exchange and/or forming Sr-solid phases. The same minerals removed up to 99.99% of the added La and Nd by forming solid carbonate, oxide, or hydroxide phases. Zeolites reacted with La and Nd to form smectite.

72. A) Gen. Cat.--Hydrothermal alteration

B) Komarneni, S.; Roy, D. M., 1983, Alteration of clay minerals and zeolites in hydrothermal brines: *Clays and Clay Minerals*, v. 31, no. 5, p. 383-391.

C) Purpose: investigate the alteration of backfill materials in simulated salt repository brines under hydrothermal conditions.

Methods: AES, AAS, XRD.

Results: Mg-rich brines are more acidic than NaCl brines under hydrothermal conditions. No alteration was observed in clay minerals treated with NaCl brine at 200°C. The only zeolites to alter to analcime under these same conditions were phillipsite and erionite. Zeolites and most of the clays did not alter in Mg-rich brine at 200°C. At 300°C in NaCl solution, clays were stable but zeolites altered to analcime or albite. In Mg-rich brine, Al-rich montmorillonite was more stable than Al-poor montmorillonite. Zeolites altered to smectites in Mg-rich brine at 300°C.

73. A) Gen. Cat.--Sorption studies

B) Miller, S. E.; Heath, G. R.; Gonzalez, R. D., 1983, Effect of pressure on the sorption of Yb by montmorillonite: *Clays and Clay Minerals*, v. 31, no. 1, p. 17-21.

C) Purpose: consider P-T effects on the irreversible fixation of lanthanide ions on montmorillonite.

Methods: wet chemical techniques, XRD, polarography, IR.

Results: irreversible sorption of Yb^{3+} increases with increasing T (20-280°C) at 1 atm., but decreases with increasing T at 110 atm. Decreased sorption is attributed to reduced hydrolytic fixation of cations and to rapid expulsion of interlayer Yb^{3+} at higher T's. Data suggest that sorbed Yb^{3+} is charged compensated by deprotonation of Fe^{3+} - and Mg^{2+} -hydroxyl groups.

74 . . A) Gen. Cat.--Adsorption

B) Laxen, D. P. H., 1984, Adsorption of Cd, Pb, and Cu during the precipitation of hydrous ferric oxide in a natural water: Chemical Geology, v. 47, no. 3-4, p. 321-332.

C) Purpose: to report studies on the adsorption behavior of Cd, Pb, and Cu onto hydrous ferric oxide under realistic conditions.

Methods: adsorption studies, chemical analyses (A.A.)

Results: initial uptake of Cd and Pb is fairly evenly distributed across all size fractions of the precipitate. However, Cu behaves unexpectedly. An initial high uptake is focussed on the small size fraction (0.1-.4 micrometers). This is followed by a steady desorption from this size fraction.

75. A) Gen. Cat.--Cation exchange or Sorption studies

B) Komarneni, S., 1985, Phillipsite in Cs decontamination and immobilization:

Clays and Clay Minerals, v. 33, no. 2, p. 145-151.

C) Purpose: show that ^{137}Cs exchanged by phillipsite tuff can be easily immobilized by the formation of crystalline Cs-aluminosilicates.Methods: XRD, AAS, spectrometric analyses, gamma counting, SEM.Results: fixation of Cs can be attained by heating phillipsite at 600°C for 4 hours and collapsing the Si-Al tetrahedral rings around Cs ions to produce a Cs-feldspar. Treatment at 800°C to 1000°C results in the formation of pollucite, $\text{CsAlSi}_2\text{O}_8$. Hydrothermal treatment at 300°C and 30 MPa will also fix Cs in pollucite.

76. A) Gen. Cat.--Cation exchange or Sorption studies

B) Moes, A.; Verheyden, D.; Cremers, A., 1985, Formation of highly selective cesium-exchange sites in montmorillonites: *Clays and Clay Minerals*, v. 33, no. 3, p. 251-257.

C) Purpose: determine the nature of high energy exchange sites on clays.

Methods: radiometric assay.

Results: characteristic free energy exchange values for the Cs^+ - Ca^{2+} exchange ranged from 40 to 6 kJ/eq. Heat treatments of montmorillonite generate a range of different site types, each with a different selectivity. Smaller site group capacities are associated with higher selectivity.

77 . A) Gen. Cat.--Sorption studies

B) Tessier, A.; Rapin, F.; Carignan, R., 1985, Trace metals in oxic lake sediments: possible adsorption onto iron oxyhydroxides: *Geochimica et Cosmochimica Acta*, v. 49, no. 1, p. 183-194.

C) Purpose: measure cation adsorption and calculate equilibrium binding constants (K_A)

Methods: AAS, gas chromatography

Results: generally, field, laboratory and theoretical data agree.

Some deviation is noted at high pHs, this may be due to the action of dissolved ligands. Significant deviation occurs at low sediment pH values.

This can be explained by the formation of ternary complexes on the Fe-oxyhydroxide surface. Adsorption onto oxyhydroxides may be important in lowering trace metal concentrations in oxic waters.

78 A) Gen. Cat.--Sorpton studies

B) Traina, S. J.; Doner, H. E., 1985, Co, Cu, Ni, and Ca sorption by a mixed suspension of smectite and hydrous manganese dioxide: Clays and Clay Minerals, v. 33, no. 2, p. 118-122.

C) Purpose: provide evidence of sorption by Mn-oxides in the presence of a competing sorbent.

Methods: wet chemical methods, TEM.

Results: 77, 67, and 69% of the total Co, Cu, and Ni, respectively, sorbed was found on MnO_2 , while only 28% of the Ca was found on this oxide. The observed differences are due to the different sorption mechanisms of MnO_2 and montmorillonite. Cation sorption by expanding clays is primarily due to coulombic attraction of the metal ions by permanent, negative charges on the clay's surface, and is strongly influenced by concentrations of all cations in solution.

VEIN DEPOSITS

1. A) Gen. Cat.--Vein deposits

B) Carpenter, R. H., 1963, Some vein-wall rock relationships in the White Pine mine, Ontonagon Co., Michigan: Economic Geology, v. 58, no. 5, p. 643-666.

C) Purpose: to define the facies of mineralization controlled by fractures and to discuss the relationship of this facies to mineralization typical of White Pine ore body.

Methods: geologic mapping, petrography, XRD, chemical analyses (x-ray spectrography), sulfur isotopes.

Results: the fracture-controlled mineralization is interpreted to have originated from low temperature (less than 105°C) hypogene solutions. These solutions deposited calcite and quartz in these fractures. The distribution of copper in the veins and halos is inferred to be due to mobilization of copper by solutions diffusing into the walls.

2 . A) Gen. Cat.--Vein deposits, Th

B) Staatz, M., 1972, Thorium-rich veins of Hall Mountain in Northern-most

Idaho: Economic Geology, v. 67, no. 2, p. 240-248.

C) Purpose: to describe the thorite-bearing veins of Hall Mountain.

Methods: geologic mapping, petrography, chemical analyses, XRD.

Results: the thorium content of 23 samples from 11 veins ranged from .0095 to 21.0 percent. Twelve samples had a thorium content greater than 1 percent. The thorium and mineral content of the veins are erratic, varying both among the veins and within an individual vein.

3 . A) Gen. Cat.--Vein deposits.

B) Barbier, M. J., 1974, Continental weathering as a possible origin of vein-type uranium deposits: *Mineralium Deposita*, v. 9, no. 3, p. 271-288.

C) Purpose: to examine the genetic problem concerning some uraniferous sites in France.

Methods: literature review.

Results: As an alternative to the hypothesis of pitchblende deposit formation by a hydrothermal process, the idea of a genesis by continental weathering is supported by the following: localization next to uraniferous rock, easy solubilization of uranium, mineralogy comparable to certain roll-type deposits, formation after that of granites, and synchronicity with important occurrences of continental sedimentation. Only geothermometric measurements are not in agreement with it.

4. A) Gen. Cat.--veins, magnetite

B) Puffer, J. H.; Peters, J. J., 1974, Magnetite veins in diabase of Laurel Hill, New Jersey: Economic Geology, v. 69, no. 8, p. 1294-1299.

C) Purpose: to describe magnetite veins, their host rocks, and their possible genesis.

Methods: petrography, chemical analyses.

Results: it is concluded that: 1) Deuteric fluids developed in at least some of the eastern Triassic diabase plutons. 2) Iron was fractionated into these fluids 3) Iron was precipitated from these fluids as: a) A second generation of magnetite where no avenue of escape was available at high temperatures, b) Magnetite veins at Laurel Hill where fluids were able to escape into a network of tension joints, and c) Magnetite ore bodies such as the Cornwall type where the fluids were able to react with carbonate rocks.

5. A) Gen. Cat.--Vein deposits

B) Ramsay, W. R. H.; Kobe, H. W., 1974, Great Barrier Island silver-gold deposits, Haurakai Province, New Zealand: Mineralium Deposita, v. 9, no. 2, p. 143-153.

C) Purpose: to describe the Great Barrier Island silver-gold deposits and their associated alteration.

Methods: petrography, XRD, electron microprobe

Results: these silver-gold deposits comprise a number of essentially east striking, quartz filled, mineralized fissures, which transect andesitic volcanics and an unconformably overlying, bedded sinter deposit of upper Tertiary to Quaternary age. Wall rock alteration is characterized by a propylitic assemblage in the least altered andesite, with argillic assemblages and silicification developed in close proximity to the veins.

6 . A) Gen. Cat.--Vein deposits, thorium

B) Staatz, M., 1974, Thorium veins in the United States: Economic Geology, v. 69, no. 4, p. 494-507.

C) Purpose: to discuss the quartz-feldspar-iron oxide-thorium-bearing veins which are known from 13 widely scattered areas in the United States.

Methods: petrography, chemical analyses (XRF, AA).

Results: in eight of the 13 areas thorium veins are associated with alkalic rocks or carbonatites, or both. Carbonatite dikes are generally found near the center of an alkalic rock intrusion whereas thorium veins are at greater distances from the center. The thorium veins are believed to have been derived from a volatile late-stage phase of the magma that formed the alkalic rocks.

- 7 . A) Gen. Cat.--Vein deposits, mechanical interpretations or Media brecciation
- B) Moore, J. M., 1975, A mechanical interpretation of the vein and dyke systems of the S.W. England orefield: *Mineralium Deposita*, v. 10, no. 4, p. 374-388.
- C) Purpose: to investigate the factors responsible for the formation of the fracture, fault, and fissure structures which contain the mineral lodes and porphyry dikes.

Methods: literature review, stress trajectory analysis

Results: The trajectory diagrams indicate that the mapped configuration of veins and porphyry dikes results from fluid pressures, exerted by the mobile cores of granite cupolas situated within a regional stressfield. The stress models also indicate that fugitive dyke magma or hydrothermal fluids, emanating from a cupola, will make the mechanically easiest exit through the flanks of the intrusion.

8. A) Gen. Cat.--Vein deposits

B) Casadevall, T.; Ohmoto, H., 1977, Sunnyside Mine, Eureka Mining District, San Juan County, Colorado: Geochemistry of gold and base metal ore deposition in a volcanic environment: Economic Geology, v. 72, no. 7, p. 1285-1320.

C) Purpose: to investigate hydrothermal processes of gold mineralization.

Methods: petrography, fluid inclusions, sulfur isotope geothermometry, K/Na geothermometry, K/Na/Ca geothermometry, chemical analyses, thermodynamic analyses.

Results: model of ore fluid composition suggests that Sunnyside ore-forming fluids were composed largely of meteoric water with major recharge areas located outside of the San Juan and Silverton calderas.

- 9 . A) Gen. Cat.--Minor veins of mineralization or Hydrothermal alteration
- B) Franklin, J. M.; Mitchell, R. H., 1977, Lead-zinc-barite veins of the Dorion Area, Thunder Bay District, Ontario: Canadian Journal of Earth Sciences, v. 14, no. 9, p. 1963-1979.
- C) Purpose: to examine the genetic relationship of these veins to the Sibley Group from both stratigraphic and structural aspects, and to examine problems of temperature of vein formation.
- Methods: petrography, chemical analyses, K-Ar dating, sulfur isotopes, lead isotopes.
- Results: the deposits formed from metal leached from either basement rocks or breakdown of Sibley sandstone matrix. Rassport dolomite, where it forms a vein wall, is highly altered to metal-enriched chert and calcite. Archean wall rocks are not altered. Sulfur isotope data indicate equilibrium between galena and sphalerite yielding a depositional temperature range of 35-135°C, and dis-equilibrium between sulfide-sulfate pairs.

10 . A) Gen. Cat.--vein deposits; element zoning

B) Kamill, R. J.; Ohmoto, H., 1977, Paragenesis, zoning, fluid inclusion, and isotopic studies of the Finlandia vein, Colqui District, Central Peru: Economic Geology, v. 72, no. 6, p. 950-982.

C) Purpose: to conduct an integrated mapping, paragenetic, fluid inclusion, and stable isotope study of a typical bonanza deposit (the Finlandia vein).

Methods: geologic mapping, petrography, fluid inclusions, oxygen and sulfur isotopes.

Results: deposition and localization of the bonanza Ag-Au ore shoots was controlled by boiling of the hydrothermal fluids early in the sequence of mineralization of the Finlandia vein, which restricted the occurrence of Ag-Au ore shoots to a narrow vertical interval.

11. A) Gen. Cat.--Vein deposits

B) Kerrich, R.; Fyfe, W. S.; Allison, I., 1977, Iron reduction around gold-quartz veins, Yellowknife District, Northwest Territories, Canada: Economic Geology, v. 72, no. 4, p. 657-663.

C) Purpose: to report determinations of the oxidation state of iron in the quartz-gold deposits at Yellowknife and to discuss the significance of the data in relation to the ore-forming process.

Methods: chemical analyses (XRF, AA).

Results: the oxidation state of primary iron in Au-bearing schists at Yellowknife exhibits a major and systematic fluctuation from background values ($\text{Fe}^{2+} / \sum\text{Fe} = .75$) toward high levels of Fe^{2+} , ($\text{Fe}^{2+} / \sum\text{Fe} = .95$). The observed reduction of iron may be accounted for by the interaction of ascending, reducing hydrothermal fluids with schists within the shear zones.

12. A) Gen. Cat.--vein deposits

- B) Kanaris-Sotiriou, R.; Gibb, F. G. F.; Carswell, D. A.; Curtis, C. D.,
1978, Trace-element distribution and ore formation in vein-
metamorphosed peridotite at Kalskaret, near Tafjord, south Norway:
Contributions to Mineralogy and Petrology, v. 67, no. 3, p. 289-295.

C) Purpose: to attempt to establish the ways in which the distribution
of trace elements may be controlled in metasomatic systems of this
type.

Methods: chemical analyses (XRF), XRD, electron microprobe.

Results: the introduced elements Ti, V, Sr, and Y show specific
enrichment in particular silicate phases in accordance with the
availability of suitable lattice sites. In contrast, the other
introduced trace elements (Cu and S) behave more like the re-
distributed elements, Cr, Ni, Mn, and Co which do not show concentration
'fronts' that can be simply related to the silicate minerals.

13 . A) Gen. Cat.-- Vein Deposits

B) Staatz, M. H., 1978, I and L uranium and thorium vein system, Bokan Mountain, Southeastern Alaska: Economic Geology, v. 73, no. 4, p. 512-523.

C) Purpose: to describe the general geology of the I and L uranium and thorium vein system at Bokan Mountain.

Methods: K-Ar dating, lead-alpha dating, chemical analyses (gamma-ray spectrometric), petrography.

Results: the veins of the I and L group are unique in that no other veins in the United States contain major amounts of both uranium and thorium, as well as rare earths. However, the I and L veins are similar in part to the quartz-feldspar-iron oxide-thorium-bearing veins found in other parts of the United States.

14. A) Gen. Cat.--Vein deposits

B) Ayora, C.; Cardellach, E.; Phillips, R., 1981, Mineralization from Vall de Ribes Area (Eastern Pyrenees, Spain): *Mineralium Deposita*, v. 16, no. 2, p. 195-204.

C) Purpose: to describe the results of study of the ore deposits to establish the mineralogy and conditions of formation of the ores and their relationship with the regional geology.

Methods: petrography, electron microprobe, XRD, fluid inclusions

Results: the veins and local replacement deposits in dolomite show a zoning in tungsten-bismuth, arsenic and antimony away from the adjacent late Hercynian Costabona granite. Wall rock alteration is almost negligible.

15. A) Gen. Cat.--Vein deposits

B) Watson, P. H.; Goivin, C. I.; and Christopher, P. A., 1982, General geology and genesis of silver and gold veins in the Beaverdell area, south central British Columbia: Canadian Journal of Earth Sciences, v. 19, no. 6, p. 1264-1274.

C) Purpose: to describe the general geology, ages of the associated intrusive rocks based on K-Ar analyses, and the age and genesis of the veins based on galena-lead isotope analyses.

Methods: K-Ar analyses, U-Pb analyses.

Results: exploration for the types of deposits in the Beaverdell area can be guided by galena-lead isotope analyses.

16 . A) Gen. Cat.--Vein deposits

B) Bray, C. J.; Spooner, E. T. C., 1983, Sheeted vein Sn-W mineralization and greisenization associated with economic kaolinization, Goonbarrow China Clay Pit, St. Austell, Cornwall, England: geologic relationships and geochronology: *Economic Geology*, v. 78, no. 5, p. 1064-1089.

C) Purpose: to contribute to the discussion on the origin of these kaolin deposits by examining the Goonbarrow deposit in detail.

Methods: petrography, chemical analyses, K-Ar dating.

Results: evidence suggests a primary hydrothermal origin for the southwest England kaolinite deposits, and gives definite arguments against an origin related to chemical weathering.

17. A) Gen. Cat.--Vein deposits, geothermometry

B) Khin Zaw, U., 1984, Geology and geothermometry of vein-type W-Sn deposits at Pennaichaung and Yetkantzintang prospects, Tavoy Township, Tennasserim Division, southern Burma: Mineralium Deposita, v. 19, no. 2, p. 138-144.

C) Purpose: to prevent fluid inclusion data of the two known primary vein-type W-Sn prospects along with their detailed surface outcrop and underground geology.

Methods: geologic mapping, petrography, fluid inclusion studies

Results: the fluid inclusion study has shown that the ore fluids responsible for the Pennaichaung and Yetkansintaung W-Sn deposits were relatively cool, diluted, CO₂-deficient NaCl brines, but it is not known on the present investigation that the source or sources of ore fluids were of magmatic and/or meteoric waters.

18. A) Gen. Cat.--Vein deposits or Hydrothermal alteration

B) Lange, I. M.; Krouse, H. R., 1984, Sulfur isotopic variations in the A2844 vein and wall rock, Butte, Montana: *Geochemical Journal*, v. 18, no. 6, p. 269-280.

C) Purpose: to conduct a detailed sulfur isotope study of a short section of a vein and adjacent wall rock.

Methods: petrography, XRD, sulfur isotopes.

Results: The $\delta^{34}\text{S}$ of the hydrothermal solution responsible for pyrite deposition is estimated to be $+3.1\text{ }^{\circ}/\text{oo}$. Disseminated wall rock pyrites are depleted in ^{34}S by as much as $2.4\text{ }^{\circ}/\text{oo}$ relative to the adjacent vein and veinlets.

19. A) Gen. Cat.--Fracture or Calcite, fissure veins

B) Larson, S. A.; Tullborg, E., 1984, Stable isotopes of fissure-filling calcite from Finnsjön, Uppland, Sweden: Lithos, v. 17, no. 2, p. 117-125.

C) Purpose: to find out the character and approximate age of calcite fracture fillings by using textural, stable isotope, and fluid inclusion data.

Methods: borehole studies, stable isotopes (D,O,C), carbon dating, petrography, fluid inclusions.

Results: fissures at Finnsjön have suffered repeated fluid activation.

Conditions varying from hydrothermal to those which prevailed during post-glacial time are reflected in calcite fillings from single fissures. This is evident by textural, fluid inclusion, and stable isotope data.

20. A) Gen. Cat.--Aureoles, vein

B) Oosteram, M. G.; Bussink, R. W.; Vriend, S. P., 1984, Lithogeochemical studies of aureoles around the Panasqueira tin-tungsten deposit, Portugal: Mineralium Deposita, v. 19, no. 4, p. 283-288.

C) Purpose: to conduct a multi-element lithogeochemical survey of aureoles at Panasqueira.

Methods: chemical analyses (XRF, AA)

Results: the multi-element parameters methods applied at Panasqueira demonstrate the relationship between geochemical anomalies and the geology of the ore deposits. The anomalies appear to reflect the distribution of elements through leakage in the joint system in the schists rather than a pervasive infiltration of the country rock in a massive and homogeneous way.

21. A) Gen. Cat.--Hydrothermal veins

B) Chil-Sup So; Se-Jung Chi,; Shelton, K. L.; and Skinner, B. J., 1985,
Copper-bearing hydrothermal vein deposits in the Gyeongsang Basin,
Republic of Korea: Economic Geology, v. 80, no. 1, p. 43-56.

C) Purpose: to present results on an investigation of the nature of the
mineralization in the Sambang region.

Methods: S isotopes and fluid inclusions.

Results: similarity of the features of the mines investigated in this
report to those of other copper-bearing deposits in Korea and elsewhere
suggests a genetic tie between granitic magmatism and the development of
the observed Cu-Pb-Zn-Ag mineralization and parageneses.

22 . A) Gen. Cat.--vein deposits

B) Nuelle, L. M.; Proctor, P. D.; Grant, S. K., 1985, Vein formation and distribution, Ohio and Mt. Baldy districts, Marysvale, Piute County, Utah, U.S.A.: Mineralium Deposita, v. 20, no. 2, p. 127-134.

C) Purpose: to report on the geologic setting, wallrock alteration, and mode of emplacement of the veins.

Methods: geologic mapping, petrography, chemical analyses (fire assay, AA)

Results: the presence of doming, boiling, the resultant mineral zonation and hydrothermal alteration, and the presence of base and precious metals along with anomalous amounts of molybdenum, suggest that the vein fluids were probably derived from an ore-generating pluton at depth.

23 . A) Gen. Cat.--Vein deposits

B) Vikre, Peter G., 1985, Precious metal vein systems in the National District, Humboldt County, Nevada: Economic Geology, Vol. 80, n. 2, p. 360-393.

C) Purpose: To describe lithologies, structures and sulfide-silicate zones of alteration in an attempt to locate more ore grade vein segments.

Methods: Geologic mapping, fluid inclusions, and thermal measurements.

Results: Distribution of alteration assemblages, precious metal minerals, stibnite and cinnabar was apparently controlled by boiling, sulfidation gradient, temperature decreases, and near-surface hydrology.

1. A) Gen. Cat.--element exchange, zeolites

B) Ames, L. L., Jr., 1960, Cation sieve properties of clinoptilolite:

American Mineralogist, v. 45, no. 5 and 6, p. 689-700.

C) Purpose: to present cation exchange data pertaining to the kinetics of Cs selectivity in clinoptilolite.

Methods: cation exchange studies.

Results: clinoptilolite was found to be highly Cs-selective over wide pH, flow rate, and temperature changes. Factors affecting clinoptilolite cation selectivities included cation size, charge, electronic structure, and, in the presence of Na, temperature.

2. A) Gen. Cat.--Element exchange

B) Ames, L. L., Jr., 1962, Kinetics of cesium reactions with some inorganic cation exchange materials: *American Mineralogist*, v. 47, no. 9 and 10, p. 1067-1078.

C) Purpose: to demonstrate that the same techniques used to describe the kinetics of organic ion exchange resins may also be utilized to describe the kinetics of inorganic cation exchanges.

Methods: cation exchange studies.

Results: By consideration of the two diffusion mechanisms of organic resins, particle and film diffusion, inorganic cation exchange kinetics also can be characterized. Determination of fundamental kinetic quantities, such as particle diffusion coefficients and average film depths, allows computation and prediction of loads and loading rates of the exchange materials under given experimental conditions.

3. A) Gen. Cat.--Element exchange, zeolites

B) Ames, L. L., Jr., 1962, Cation sieve properties of open zeolites:

American Mineralogist, v. 46, no. 9 and 10, p. 1120-1131.

C) Purpose: to study the partial cation seive properties of "open" zeolites in an effort to determine the mechanism responsible for the type and intensity of the observed cation replacement series.

Methods: cation exchange studies

Results: it was found that neither the hydration state of the cations before entering the zeolite structure nor relative loading rates had any significant effect on the type or intensity of alkali metal or alkaline earth metal cation replacement series.

4 . A) Gen. Cat.--Element exchange, zeolites

B) Ames, L. L., Jr., 1962, Effect of base cation on the cesium kinetics of clinoptilolite: *American Mineralogist*, v. 47, no. 11 and 12, p. 1310-1316.

C) Purpose: to study the effects of base cation on the cesium loading kinetics of clinoptilolite.

Methods: loading kinetics studies

Results: results showed cesium loading on lithium clinoptilolite to be the most rapid, and cesium loading on hydrogen clinoptilolite to be among the slowest reactions. Cesium loading on hydrogen-based clinoptilolite would be faster if cation liquid diffusion velocities alone were rate-controlling. Both the hydrated replacement series and loading kinetics are influenced by cation-zeolitic water-anionic site interactions.

5. A) Gen. Cat.--Element exchange, zeolites

B) Ames, L. L., Jr., 1962, Characterization of a strontium-selective zeolite: American Mineralogist, v. 47, no. 11 and 12, p. 1317-1326.

C) Purpose: to examine a group of several zeolites for the ability to selectively remove small amounts of strontium from aqueous wastes containing high concentrations of sodium salts.

Methods: equilibrium, statistical, kinetic and column techniques and data to choose an appropriate zeolite.

Results: Type A zeolite was the most selective of the group for strontium, but more than a simple reversible exchange reaction was responsible for this strontium selectivity.

6 . A) Gen. Cat.--Zeolites

B) Ames, L. L., Jr., 1963, Mass action relationships of some zeolites in the region of high competing cation concentrations: American Mineralogist, v. 48, no. 5 and 6, p. 868-882.

C) Purpose: to provide data on zeolite strontium and cesium exchange equilibria.

Methods: petrography, XRD, cation exchange capacity measurements.

Results: Cesium mass action quotients generally declined in going from cesium-sodium to cesium-rubidium systems. Structural differences between two members of the same zeolite species often resulted in cation exchange equilibria differences as great as those between different species.

7. A) Gen. Cat.--Zeolites, exchange equilibria

B) Ames, L. L., Jr. ,1964, Some zeolite equilibria with alkali metal cations: American Mineralogist, v. 49, no. 1 and 2, p. 127-145.

C) Purpose: to derive the thermodynamics of several alkali metal cation exchange equilibria.

Methods: thermodynamic analyses, cation exchange studies.

Results: cation exchange equilibria for natural zeolites and synthetic zeolites in the systems sodium-cesium, potassium-sodium, and potassium-cesium are presented along with derived thermodynamic data. Gibbs free-energies and enthalpies for the various exchange reactions were relatively small. Reaction enthalpies diminished as the sizes of the two exchanging cations approached one another. Thermodynamic data proved to be useful in several cases for interpretation of zeolite equilibria but proved to be most valuable when used in correlation with other properties of the zeolite exchange systems.

8. A) Gen. Cat.--Zeolites, exchange equilibria

B) Ames, L. L., Jr., 1964, Some zeolite equilibria with alkaline earth metal cations: *American Mineralogist*, v. 49, no. 7 and 8, p. 1099-1110.

C) Purpose: to discuss zeolite cation exchange equilibria of strontium and calcium-containing systems.

Methods: thermodynamic analyses, using samples described in a previous paper (Ames, 1964).

Results: thermodynamic data derived from the isotherms of the zeolites studied indicated that reaction enthalpies are very small from 25°C to 70°C. An inverse relationship was noted between $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratios and divalent cation selectivities.

9. A) Gen. Cat.--Zeolites, exchange equilibria

B) Eberly, P. E., Jr., 1964, Adsorption properties of naturally occurring erionite and its cationic-exchanged forms: *American Mineralogist*, v. 49, no. 1 and 2, p. 30-40.

C) Purpose: to present results on the adsorption of various C_5 to C_7 hydrocarbons on this sample of erionite and its ion-exchanged forms for comparison with the known behavior of synthetic zeolite A.

Methods: ion-exchange studies, adsorption measurements, XRD.

Results: the effective pore diameter for erionite lies between 4.5 and 5.4 Å. This is in agreement with the crystal structure which indicates elliptical pore openings having a major and minor axis of 4.7-5.2 Å and 3.5 Å, respectively. Exchange of 15% of the cationic equivalents with potassium results in a material having capacity only for water. Calcium exchange nearly doubles the adsorptive capacity for n-pentane

10. A) Gen. Cat.--Zeolites, ion exchange

B) Taylor, A. M.; Roy, R., 1964, Zeolite studies IV: Na-P zeolites and the ion-exchanged derivatives of tetragonal Na-P: American Mineralogist, v. 49, no. 5 and 6, p. 656-682.

C) Purpose: to demonstrate the possible extent, composition-wise, of this zeolite group and to present x-ray and other data for the known zeolite members.

Methods: zeolite synthesis, XRD, cation exchange studies

Results: new analyses of the Na-P group zeolites are given, and the analyses available show that the $\text{Al}_2\text{O}_3:\text{SiO}_2$ ratio ranges from at least 1:3.18 to 1:5.26. The effect of ion-exchange on the structure of Na-P_t (Na_2O , Al_2O_3 , 3.63 SiO_2 , 4.31 H_2O ; tetragonal, $a = 10.11 \text{ \AA}$, $c = 9.83 \text{ \AA}$) is considerable; a maximum range of 7% exists in the c-dimension of the tetragonal unit cells of the ion-exchanged forms.

11 . A) Gen. Cat.--Zeolites, cation diffusion

B) Ames, L. L., Jr., 1965, Self-diffusion of some cations in open zeolites: American Mineralogist, v. 50, no. 3 and 4, p. 465-475.

C) Purpose: to study the diffusion of sodium, strontium, and cesium in natural and synthetic zeolites.

Methods: cation diffusion coefficient measurements.

Results: sodium, strontium and cesium self-diffusion coefficient measurements in the natural zeolites erionite, phillipsite, and clinoptilolite, and the synthetic zeolites Linde Type A and Type X are $1 \times 10^{-9} \text{ cm}^2/\text{sec}$ to $5 \times 10^{-7} \text{ cm}^2/\text{sec}$ in aqueous systems at 50°C .

12 . A) Gen. Cat.--zeolites, diagenetic

B) Sheppard, R. A.; Gude, A. J., III.; Munson, E., 1965, Chemical composition of diagenetic zeolites from tuffaceous rocks of the Mojave Desert and vicinity, California: *American Mineralogist*, v. 50, no. 1 and 2, p. 244-249.

C) Purpose: to report some chemical analyses of diagenetic zeolites.

Methods: chemical analyses

Results: article only reports chemical data, and does not interpret it .

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BOX 6