Summary of Economic Geology Study and Resource Potential of the Pasco Basin, Washington and Vicinity - Draft Final Report

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DRAFT FINAL REPORT

ECONOMIC GEOLOGY STUDY AND RESOURCE POTENTIAL OF THE PASCO BASIN, WASHINGTON, AND VICINITY

Summary

Geological resources of the Hanford site and its environs are assessed relative to occurrence and development potential. Resources described are minerals, fossil fuels, groundwater and spent fuel radioactive waste.

Possibly important structural and stratigraphic relationships relative to possible resources:

1. East-west magnetic anomalies possibly suggesting an aulacogen
2. Northwest and north northwest trending lineaments and fault zones
3. A projected southeast extension of the Chiwaukum graben
4. A projected southwest extension of the Kootenay Arc embayment
5. A strontium isotope province discontinuity
6. Thickening of a sub-basalt conductive layer in Pasco Basin
7. Sub-basalt faulted pluton margins

Most valuable resource in the next 50 years in the immediate site area will be spent fuel radioactive waste. Only oil and gas represent moderate likely mineral resources in the site area.

Verifications recommended:

1. isotopic analysis of methane to determine origin
2. geophysical surveys of northern Pasco Basin, especially where east-west anomaly and Olympic-Wallowa lineament intersect
3. determine peat quality at Crab Lake for fuel and fertilizer potential
4. engineering barrier studies of repository shaft fillings for economic analysis of waste retrievability

1.4 Setting

Pasco Basin is an intermontane plateau between the Pacific (Cascade Mountains) and Columbian (Rocky Mountains) Orogens. Columbian comprises deformed cratonic margin sediments hosting Late Proterozoic to Early Paleozoic mineral deposits. Pacific Orogen comprises possibly allocthonous sediments with respect to the craton, hosting Mesozoic deposits closely associated with volcanic rocks.

Site area of Pasco Basin is underlain by a bedrock of at least 4000 feet of Columbia River basalts 0-700 feet of Pliocene and Pleistocene stream and lake deposits cover the basalt. Interbedded volcaniclastic sediment layers can be found in upper sections of the basalt.

2.0 Purpose and Scope

Main objectives:

1. determine worth of high-unit value deposits within 100 km of proposed site
2. locate resources with respect to the site
3. specify potential for present non-economical resources, within 100 km radius, to become economical
4. determine if spent fuel wastes are a potentially valuable resource under 50 year retrievability and land status constraints

3.0 Map Presentation

1. land status, well sites, and geophysical surveys around site
2. hydrological
3. mineral resource from 100 to 320 km away from site

4.0 A Review of the Groundwater Aquifers in the Pasco Basin, Washington

Introduction

Summary is based upon distinctly limited data of variable quality

Unconfined Aquifers

Hanford Site water table aquifer is geologically and hydrologically similar to aquifers in other surrounding areas. PNL modelling indicates 30 cfs of reactor affluent and process cooling waters and 2 cfs of natural recharge enters the Columbmia River from Hanford Site's unconfined aquifers.

Confined Aquifers

Where adequate data was obtained, high-yield portions of the confined aquifers are in breccias. Breccias apparently formed as streams cut along advancing basalt flows; their form resembles linear stream courses.

No predictions can be made regarding the potential of high-yield aquifers in the basalt beneath the Hanford Site.

Yield Rates

Total of 35,000 acre feet of water suggested for all wells, for irrigation, domestic, municipal, and industrial uses. Figure based upon suggested yields of 600 wells in Pasco Basin where data was available and estimation of the duration of their use per year.

Summary and Conclusions

Groundwater provides 5-10% of current total water uses in Pasco Basin, with confined and unconfined aquifers each providing about half of that percentage.

High-yield zones related to irrigated districts suggesting a significant amount of recharge is derived from irrigation water. Amount is unknown.

Present data does not permit determination of potential of water availability. More data is needed.

5.1 Structural and Stratigraphic Controls of Mineral Deposits (outside site area to 320 km)

Major structures in the area:

1. La Grande fault zone
2. Olympic-Wallowa lineament
3. East-west magnetic trend
4. Chiwaukum graben with mafic intrusion border alignment
5. Kootenay Arc

Extrapolation of above structures into Pasco Basin below Columbia River basalts could conceivably localize mineralization beneath a proposed site. Quality and quantity of data to do this vary widely. However, even if the structures did extend and were mineralized, exploitation, except for oil and gas, would be economically unfeasible.

5.1.1 La Grande Fault Zone

Major fault and lineament trends in north-east Oregon coincide in direction and age range with inferred dike swarms (from low-altitide magnetic survey.)

Small amount of slip in La Grande could have produced tension fractures into which dikes feeding the Columbia Plateau lavas were injected.

no significant mineral deposits

5.1.2 Olympic-Wallowa Lineament (OWL)

location not precisely defined

Magnetic data supports hypothesis of continental crust under Plateau north of OWL and oceanic crust to the south of OWL with a transition zone in between.

Mineralization along OWL may be related to and localized in the Mt. Aix area east of Mr. Rainier. If relationship exists, then mineralization began during and shortly after early Oligocene batholithic emplacement. Oligocene fracturing and shearing along batholoith provided passage-ways and sites for mineral deposition with hydrothermal solutions provided by the batholith. Late Oligocene rhyodacite intrusives also brought mineralizing solutions to the shear zones. Unknown which intrusive event caused the fracturing.

remote possibility of high-unit value metallic deposits within or below Pasco Basin basalts

5.1.3 East-West Magnetic Lineaments

Lineaments in Pasco Basin parallels late Tertiary Saddle Mountain trend and east-west course of the Columbia River south of Saddle Mountain.

Aspects of Columbia Plateau magnetic trends

1. cancelling out of alternating reversed and normal basaltic flow polarities may lead to detection of sub-basaltic structures
2. sub-basaltic structures may show up more clearly on high (vs low) altitude magnetic surveys

Geologic features coinciding with approximate trend or with lineament boundaries:

1. two mercury deposits
2. Pleistocene andesites
3. Yakima thermal zone
4. crust thinner in Pasco Basin

5. basalt believed to thicken southward in Pasco Basin
6. believed triple point

Above features support possibility of an aulacogen

Mineralization potential minimal, although higher potential in northern part of Pasco Basin vs. southern portion

5.1.4. Chiwaukum Graben

Graben contains Swauk formation, which is late Cretaceous and/or Paleocene or Eocene fluviatile sediments. Intertongues with fanglomerate of metamorphic detritus.

Low temperature environments don't preclude oil and gas occurrences in Swauk and could subsequent to Swauk deposition, permit oil formation without metamorphism beyond zeolite facies. Oil/gas occurrences could be extrapolated into Pasco Basin, but evidence for extension can't be rigorously documented.

Low priority on petroleum potential of Swauk if present in Pasco Basin because:

1. magneotelluric data suggests Kootenay Arc may extend into Pasco Basin rather than the graben

2. gravity and magnetic maps don't reflect graben extending southward; however, structure may be obscured by the basalt.

3. no oil found in exposed Swauk sediments

5.1.5. Kootenay Arc

Arc deformed rocks of Late PreCambrian to Mid-Jurassic ages, with metamorphism generally of chlorite-muscovite facies and locally up to sillimanite facies

Late Jurassic to Early Cretaceous (90-160 m.y.) batholiths emplaced into folded rocks. Mid-Jurassic was probable time of major folding.

Pb,Zn ores in carbonates emplaced in Paleozoic by circulating waters/brines. Pb in part mobilized sometime between early Triassic and late Jurassic and recrystalized via contact metamorphism with batholith in late Jurassic and Cretaceous.

Two broad types of mineralization:

1. earlier: shows preferential orientations; predominantly pyrite, sphalerite, galena; within Reeves limestone and related to dolomitization and silicification
2. later: pyrite galena, sphalerite, tetrahedrite and chalcopyrite with quartz, carbonate and scheelite veins

highest potential for mineralization relative to extension of Arc into Pasco Basin, especially in view of northeast trending conductive layer in the basin.

5.2 Strontium Isotope Discontinuity

No control points available for projection of Sr^{86}/Sr^{87} discontinuity into Columbia Plateau province.

5.3 Major High-Unit Value Resource Provinces

Most metallic resources of Northwest are found in metaliferous lodes associated with widespread granitic intrusives of Cretaceous and early Tertiary age

regions outside site with significant ore bodies:
1. Coeur d'Alene Belt = PreCambrian metasediments
2. Eastern Okanogan Cordillera = Paleozoic metasediments
3. Oregon Blue Mountains = Mesozoic metasediments

5.3.1 Coeur d'Alene (ore bodies)

Emplaced in late Cretaceous. Age dating gives PreCambrian ages but geologists experienced in the district concur on younger age.

Located in linear belts following monzonite stock intrusions

5.3.2. Eastern Okanogon Province

Mid-Cretaceous deformation accompanied by widespread granitic intrusives produced dolomitization of Cambrian carbonates and apparently accompanied by Pb-Zn mineralization.

5.3.3 Blue Mountain Province

Late Paleozoic and Mesozoic sediments host post Jurassic intrusives. Primary emplacement of ores in quartz dikes associated with quartz diorite intrusive masses.

Quartz diorite pluton created avenues and solutions for subsequent hydrothermal mineralization of mostly pyrite, marcasite, and chalcopyrite, with local galena, sphalenrite, stibnite

5.4. Regional Geochronologic and Ore Deposits

From site area to 320 km, many base metal ore deposits are directly or indirectly associated with post intrusion hydrothermal activity around a pluton.

Two major periods of intrusive activity in the Pacific Northwest. 65-105 m.y. and 130-160 m.y. 130-160 m.y. period suggested by limited data (Fig. 5.8)

Age and distribution of plutons closely related to genesis of ore deposits. Mineralization common close to pluton margins and often near lineament intrersections.

No high-unit value producing mines within 100 km of site. Potentially significant resources for use at Hanford (Table 5-2)

beryllium	thorium	caliche
cadmium	uranium	diatomite
lithium	zirconium/hafnium	sand/gravel
peat	processed basalt	

5.6.3 Inventory of Resources of Site Area High-Unit Value - Metallic Resources

None

5.6.4 Inventory of Resource of Site Area Predominantly Low Unit Value - Non-Metallic Resources

Eight clay quarries of peripheral interest due to ability of some clays to fix specific radioactive isotopes that may be carried in groundwater

6.1 Description of Fossil Fuel and Uranium Resources

6.1.1 Inventory External to Site Area

6.1.1.1 Coal

Centralia mine has more than enough coal to a strippable depth to serve projected additional energy needs of the Northwest (exclusive of imports) for 200+ years based upon need of 1000 MW of energy pre year to keep pace with growth.

6.1.1.2 Oil and Gas

One producing field within 320 km of proposed site. Former gas production from Rattlesnake Hills field within site area

6.1.1.4 Uranium

Current production entirely from Stevens County, Washington

Age of primary emplacement assumed to be late Cretaceous to early Tertiary with redistribution and supergene enrichment in mid-Tertiary

6.1.2 Inventory and Assessment Internal to Site Area

6.1.2.1 Coal

Two potential sources:

1. within Columbia River basalts
2. below Columbia River basalts

sub-basalt

Indirect evidence for sub-basalt potential:

1. Pasco Basin is a structural basin which could contain coal bearing sediments
2. possible coal-rich conductive layer below basalt
3. Pasco Basin below basalt is possibly analogous to existing, small, isolated, non-marine Tertiary coal-rich basins in eastern Washington

4. methane in Rattlesnake Hills possibly coal-derived pending isotopic analysis of the gas; present concensus supports inter-basalt origin

little hard evidence available; drilling needed to determine sub-basalt strata

inter-basalt

evidence to support non-commercial deposits:
1. coal occurs presumably in lower Ellensburg fm in Rattlesnake Hills #1 well (from well cuttings)
2. coal found in Latah fm (Idaho) in analogous conditions to Rattlesnake Hill

methane should be isotipically analyzed for presence of C^{13} with respect to C^{12}. High C^{13} suggests a shallow or inter-basaltic origin.

6.1.2.2. Oil and Gas

Gas produced in Rattlesnake Hills well

Typical gas analysis shows nitrogen contamination and an absence of heavier hydrocarbons. Supports inter-basalt methane origin theory.

Isotope analysis suggested: methane under high temperature and pressure is enriched in heavy carbon and heavy hydrocarbon fractions. Three wells in particular cited for analysis.

Favorable oil/gas exploration zone criteria:

1. thick sediments as source rock
2. thin basalt cover
3. favorable structural traps

Two sites within site area selected based upon criteria

6.1.2.3 Uranium

Possible sources in site area

1. below basalt cover
2. within Ellensburg fm

Unknown potential for uranium mineralization in metasediments bordering subjacent pre-Miocene plutons penetrating basement.

Exploitation economically prohibitive even if deposit did exist and was pinpointed.

Beverly ash fall tuff in lower Ellensburg extremely significant if considered as possible source area for lateral groundwater transport of uranium into repository area. Arkosic units with calcareous linses, which lies beneath the ash fall, could precipitate out uranium in the groundwater

Critical questions about possible uranium salt concentrations in site area:

1. Are the radioactive tuffs permeable enough to permit movement of uranium salts leached from the tuffs?

2. What is the leachable fraction of the radioactive constituents of the tuffs?

3. What is the direction of groundwater movement? Could the uranium be transported the repository in the groundwater?

4. What is the continuity of the Beverly ash fall and its calcareous "facies" or subsurface caliche horizons near the repository?

Local small pockets of uranium could conceivably occur in the repository site.

7.1 Buried Nuclear Waste

7.1.1 Introduction

Buried wastes could be the resource with highest potential for development in the next 50 years within the site area. Could represent potentially high grade "ore" enriched to over 95% uranium and small amounts of plutonium

Potential significance of on-site buried, unreprocessed repository waste is that a future full-scale breeder reactor could utilize components of the waste

7.3.1 Unreprocessed LWR Fuel

Composed of 96 weight % of UO_2 and 4% fission products and actinides

If uranium is oxidized to the +5 valence state its fission products will be more readily leached. However, within a 50-year retrievability period, it is unlikely that marked oxidation of uranium to the +5 state will occur

7.4 Productivity, Availability, and Value of Nuclear Wastes in the United States

DOE estimates 98,000 tons of commercial spent fuel in the U.S. by year 2000 and 315,000 tons total for the free world. At a 1965 estimate of by-product value of $232,538 per ton, the US tonnage is equivalent to $22.7 billion and $73.2 billion for the free world.

1965 estimate does not take into account:

1. inflation
2. potential new applications for by-products
3. new national strategic material considerations
4. partial neutralization of associated radioactivity in order to store the wastes
5. recent advances in by-product extraction, e.g., laser isotope separation and photochemistry

Estimated cumulative costs through year 2000 for handling all nuclear waste in US is $18-23 billion (1978 dollars)

Small percentage of U^{235} and Pu^{239} in marginal chain reaction level fuel may appreciate in value if mineable uranium mineral supply decreases to a critical stage.

7.6 Unique Aspects of Nuclear Waste Retrievability

Aspects favorable to retrievability:

1. quality, quantity, depth, and location of ore is known
2. repository can be filled and sealed in such a way as to make retrievability that much easier
3. wastes can be retrieved at specific periods for isotopes needed at specific radiation levels within a 50-year period

Projections suggest real need for enriched uranium in order that nuclear power continues

Hanford could constitute one of the most concentrated and valuable ore deposits in the Northwest if point 2 above is kept in mind

8.0 General Assessment of Resource Potential Development

Site area and Pasco Basin has five potential geologic resources:

1. groundwater in confined and unconfined aquifers
2. high-unit value metallic resources
3. high-unit value uranium and fossil fuels, including coal and oil/gas
4. low-unit value sand and gravel
5. high-unit value nuclear waste products

Potential for each can be determined fully through detailed geotechnical exploration programs under construction of Federal and socio-economic constraints

Only oil/gas and nuclear wastes may be of sufficient quantity and value to recover within the NRC imposed 50-year limit

Basalt thickness precludes any mining below it, and fossils fuels, exclusive of oil and gas, are concluded to be too small to warrant exploration. Low-unit value resources in the Pasco Basin are too widespread and locally too plentiful to bother exploring and developing

8.2 High-Unit Value Metallic Resources

Approaches to assess potential metallic resources:

1. Evaluate probability of encountering felsic intrusions and their margins. Felsic plutons are often more highly mineralized than mafic ones and their margins are apt to be more highly fractured, and thus more mineralized in their cores

2. Place equivalent site area and shape on portion of surrounding 320 kms richest in known metallic resources; this indicates the highest probability, after noting the number of deposits of various types and areas in the richest province, of randomly encountering a significant ore body

   With respect to the first approach, no well defined magnetic anomaly is present in the site area to be interpreted as a pluton. However,

similar resistivities of metasediments and felsic plutons could produce a masking effect

Under approach two, the Kootenay Arc is the richest metallic province and the chances of randomly finding on ore is only .017%. Therefore, the site area chances would be much lower.

Different approaches to determining probability of success in actually finding an ore deposit all give the answer as remote in the site area

8.3 High-Unit Value Fossil Fuels

8.3.1 Coal-Specific Assessment Considerations

Sediments of Rattlesnake Hill appear devoid of any significant coal seams

8.3.2 Coal and Peat - General Assessment

Costs of mining the coal and disposing of the waste products are prohibitive for Centralia mine to supply energy for area prior to operation of a reactor

Peat deposit at Crab Lake too small for extended energy needs

8.3.2 Oil and Gas

On basis of source beds of unknown but presumedly small areas, unknown stratigraphic trap conditions, poorly estimated structural trap volumes, a minimum thickness of at least 10,000 feet of capping basalt, and a relatively small reservoir volume potential for postulated traps within the two proposed sites, it is concluded that a minor to moderate potential exists for oil/gas development

8.3.3 Uranium

Very small possibility of sub-basalt uranium deposits and no reasonable way to recover it if it did exist

Virtually no development potential for uranium in caliche below Beverly ash falls based upon

1. low concentrations of leachable uranium in the ash falls
2. unknown relationship between groundwater movement and caliche horizons
3. presumed variability of groundwater movement with time
4. absence of any known mineralization either in the ash falls or the caliche

9.0 Conclusions and Recommendations

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