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July 11, 2001
Contract No. NRC–02–97–009
Account No. 20.01402.871

U.S. Nuclear Regulatory Commission
ATTN: Dr. John W. Bradbury
Division of Waste Management
Two White Flint North
Mail Stop TD–13
Washington, DC 20555

Subject: Transmittal of the deliverable "Summary and Synthesis of Characterization Data Relevant to Radionuclide Transport through Alluvium in the Vicinity of Yucca Mountain, Nevada—Letter Report" (IM 01402.871.100).

Dear Dr. Bradbury:

The enclosed paper is identified as IM 1402.871.100 in the CNWRA Operations plans for the Key Technical Issue on Radionuclide Transport. The final title of the report is "Summary of Early Warning Drilling Program Data Relevant to Radionuclide Transport in the Alluvium South of Yucca Mountain, Nevada."

The alluvium within Fortymile Wash is an important part of the potential saturated flow and transport path from the proposed repository to the biosphere; however, it is not yet adequately characterized. The Nye County Early Warning Drilling Program (EWDP) is the primary data source for the U.S. Department of Energy (DOE) for characterizing the alluvium. This report provides available geochemical data from the EWDP as well as independent results of mineralogical and chemical analyses of well cuttings from selected EWDP wells within Fortymile Wash obtained at the CNWRA. Electronic versions of the data files are provided on the attached CD. For the convenience of U.S. Nuclear Regulatory Commission (NRC) staff, tabular data are provided in both Excel and Quattro Pro formats.

Data contained in this report will be an important resource for regulatory reviews and model development as NRC evaluation of the DOE Yucca Mountain characterization program proceeds. If you have any questions regarding this submittal, please contact me (210-522-5540) or Mr. Paul Bertetti (210-522-5228).

Sincerely,

English C. Pearcy
Element Manager
Geohydrology and Geochemistry

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/ar

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SUMMARY OF EARLY WARNING DRILLING PROGRAM DATA RELEVANT TO RADIONUCLIDE TRANSPORT IN THE ALLUVIUM SOUTH OF YUCCA MOUNTAIN, NEVADA

Prepared for

Nuclear Regulatory Commission
Contract NRC–02–97–009

Prepared by

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July 2001

ABSTRACT

The U.S. Department of Energy (DOE) is currently investigating Yucca Mountain, Nevada as a potential site for geologic disposal of high-level waste. The potential for radionuclides to be transported in groundwater from the proposed repository to the accessible environment is a key technical issue for the U.S. Nuclear Regulatory Commission, and the potential delay of the transport of radionuclides in groundwater has been identified as principal factor in the DOE safety case. The alluvium within Fortymile Wash is an important part of the saturated flow and transport path from the repository to the biosphere, yet it is not adequately characterized. The Nye County Early Warning Drilling Program (EWDP) is the primary data source for the DOE for characterizing the alluvium. This report provides available geochemical data from the EWDP as well as independent results of mineralogical and chemical analyses of well cuttings from two EWDP wells within Fortymile Wash obtained at the CNWRA. The data files are provided in electronic format on the attached CD.

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ACKNOWLEDGMENTS

This report was prepared to document work performed by the Center for Nuclear Waste Regulatory Analyses (CNWRA) for the U.S. Nuclear Regulatory Commission (NRC) under Contract No. NRC–02–97–009. The activities reported here were performed on behalf of the NRC Office of Nuclear Material Safety and Safeguards, Division of Waste Management. The report is an independent product of the CNWRA and does not necessarily reflect the view or regulatory position of the NRC.

The authors would like to thank R. Downing (Nye County) and C. Glenn (NRC) for their assistance in obtaining Early Warning Drilling Program analytical results for Nye County and U.S. Department of Energy studies, respectively. The authors also acknowledge the technical review of D. Turner and the programmatic review of B. Sagar. Special appreciation is also due to A. Ramos for his assistance and support in the preparation of this report.

QUALITY OF DATA, ANALYSES, AND CODE DEVELOPMENT

DATA: CNWRA-generated original data contained in this report meet quality assurance (QA) requirements described in the CNWRA QA manual. Sources for other data should be consulted for determining the level of quality for those data.

ANALYSES AND CODES: The graphics interface program JADE (Materials Data Inc., Livermore, CA) was used to generate and analyze x-ray diffraction patterns. The spreadsheet software programs Microsoft™ Excel 97 and Corel® Quattro Pro 8, and the database software AquaChem (Version 3.7, Waterloo Hydrogeologic) were used in calculations and to generate some figures for this report. The graphical plotting software SigmaPlot (Version 5, SPSS Scientific) was also used for some figures. These codes are not controlled under CNWRA Software Configuration Procedures as these are commercial software packages and only the object codes are available to the CNWRA.

1 INTRODUCTION

1.1 REGULATORY BASES

The U.S. Department of Energy (DOE) is currently evaluating Yucca Mountain, Nevada, as a potential geologic repository for high-level nuclear waste (HLW) (Civilian Waste Radioactive Management System Management and Operating Contractor, 2000a). As part of the evaluation the geological and geochemical characteristics of the surrounding areas, especially those areas that have been predicted to be along the flow path down-gradient of Yucca Mountain, are being studied. Adequate site characterization is important because performance assessments of Yucca Mountain, which attempt to discern the safety of the potential repository over the regulatory time-period of 10,000 yr, depend on input data that are realistic and representative of the natural system. Characterization activities also produce data that help to describe the uncertainty and range of values used for modeling parameters. DOE has identified the delay of radionuclides through the saturated zone as a principal factor in their repository safety strategy (Civilian Waste Radioactive Management System Management and Operating Contractor, 2000a,c). DOE sensitivity studies have shown that the saturated zone flow path characteristics used in performance assessment models, including those of the saturated alluvium, have a potentially large impact on model results (Civilian Waste Radioactive Management System Management and Operating Contractor, 2000c). Furthermore, an independent barrier neutralization analysis conducted by the U.S. Nuclear Regulatory Commission (NRC) concluded that removal of retardation processes in the saturated zone resulted in performance assessment model doses that were five times higher than when these processes were included in performance assessment, although the dose was still below the anticipated regulatory limit (U.S. Nuclear Regulatory Commission, 1999). The recently promulgated U.S. Environmental Protection Agency (EPA) regulation, *Public Health and Environmental Protection Standards for Yucca Mountain, Nevada* (40 CFR Part 197), specifies allowable exposure limits to the public from a potential HLW repository at Yucca Mountain and provides limits on the allowable concentration of radionuclides within groundwater at Yucca Mountain. The EPA standards consider compliance locations down-gradient from Yucca Mountain to be approximately 18 km from the proposed repository. The flow path down-gradient from Yucca Mountain is believed to consist of saturated volcanic tuffs which transition into saturated alluvial sediments (Civilian Waste Radioactive Management System Management and Operating Contractor, 2000b,d). However, detailed characterization of the saturated alluvium began only within the last two years, and the data collected as a result of the characterization efforts have not been widely available (U.S. Nuclear Waste Technical Review Board, 2000; Civilian Waste Radioactive Management System Management and Operating Contractor, 2000b,c,d).

The NRC is responsible for determining if the proposed Yucca Mountain repository satisfies the EPA standards and complies with NRC regulations for licensing a repository at Yucca Mountain. NRC has identified several key technical issues (KTIs) that are central to repository performance. One of these KTIs, radionuclide transport, and its associated integrated subissue radionuclide transport in the saturated zone, is concerned with the issue that radionuclide concentrations may be reduced in groundwater during transport from the potential repository at Yucca Mountain (U.S. Nuclear Regulatory Commission, 2000a). This issue addresses features and processes that would affect movement of radionuclides in the saturated zone between the area beneath the proposed repository site at Yucca Mountain and the proposed 18-km compliance boundary. NRC has been reviewing DOE's site characterization activities and investigations to identify and resolve potential licensing issues. As part of that review, NRC conducts independent investigations related to characterization. A more detailed independent survey of radionuclide transport issues relevant to the proposed repository may be found in the Radionuclide Transport Issue Resolution Status Report (U.S. Nuclear Regulatory Commission, 2000a).

The alluvial flow path is a source of significant uncertainty in modeling radionuclide transport in the saturated zone (U.S. Nuclear Regulatory Commission, 1999, 2000a). DOE process and performance assessment models of transport through alluvium depend to a large degree on non-site-specific data (Civilian Waste Radioactive Management System Management and Operating Contractor, 2000b,c,d), and the NRC staff has raised questions regarding the adequacy of DOE's plans for future data gathering.[1] For example, this uncertainty is related to DOE's reliance on the Nye County Early Warning Drilling Program (EWDP) to provide at-depth characterization of the alluvial portion of the transport path. It is desirable for drill hole samples to be representative of the full range of lithologies and water chemistries present within the expected flow paths. The number and placement of drill holes through the alluvium needs to be adequate for characterizing spatial variations in mineralogy and lithology. Morever, DOE may be forced to rely on drill cuttings for obtaining alluvium samples, which may adversely affect DOE's ability to accurately measure sorption coefficients, surface area, and effective porosity—all of which may vary considerably in alluvial strata. In addition, it is not yet clear that DOE will obtain sufficient information on colloid transport characteristics of the alluvium.

To address licensing concerns regarding issues such as radionuclide transport through saturated alluvium at Yucca Mountain, NRC and DOE conducted a series of DOE and NRC technical exchanges during 2000 and 2001.[2,3] The products of these technical exchanges are agreements that form part of the basis for the issue resolution process. These agreements represent a commitment by DOE to provide information that the NRC staff requires for a complete, high-quality license application. Several of the agreements pertain directly to DOE's characterization efforts in the saturated alluvium.[4,5] Examples of DOE agreements to provide additional information and analyses include:

- Agreement to provide information demonstrating that DOE site characterization plans, including work on EWDP wells, the Alluvial Testing Complex (ATC), and related laboratory studies, will ensure that data on transport properties of the alluvium are sufficient to support a license application.

- Agreement to continue sorption coefficient (K_D) experiments on alluvium using samples obtained from the existing drilling program. Alternatively, DOE will consider supplementing the samples available for testing from the alternatives presented in the agreements. K_D parameter distributions for total system performance assessment (TSPA) will consider the uncertainties that arise from the experimental methods and measurements.

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[1]U.S. Nuclear Regulatory Commission. *Summary Highlights of U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Radionuclide Transport, December 5–7, 2000.* Letter from C. William Reamer (NRC) to Dennis R. Williams (DOE). Washington, DC: U.S. Nuclear Regulatory Commission. 2000c.

[2]Ibid.

[3]U.S. Nuclear Regulatory Commission. *Summary Highlights of U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Unsaturated and Saturated Flow Under Isothermal Conditions, October 31–November 2, 2000.* Letter from C. William Reamer (NRC) to Dennis R. Williams (DOE). Washington, DC: U.S. Nuclear Regulatory Commission. 2000d.

[4]U.S. Nuclear Regulatory Commission. *Summary Highlights... Management Meeting ... December 5–7, 2000.*

[5]U.S. Nuclear Regulatory Commission. *Summary Highlights...Management Meeting... October 31–November 2, 2000.*

- Agreement to provide results from alluvial field and laboratory testing, including using data obtained from the Nye County drilling program, to justify the range of flow and transport parameters used in performance assessment modeling of the alluvium and to demonstrate that performance assessment modeling captures the spatial variability of parameters affecting radionuclide transport in alluvium.

1.2 NYE COUNTY EARLY WARNING DRILLING PROGRAM

As noted previously, DOE's characterization program in the saturated alluvium relies heavily on support and cooperation from Nye County, through Nye County's EWDP. Because the proposed repository at Yucca Mountain is located within Nye County, Nevada, Nye County is afforded special status by the U.S. Nuclear Waste Policy Act of 1982, as amended. This status as an affected unit of local government provides for Nye County's participation in the Yucca Mountain program. Through agreement with DOE, Nye County has requested and received funds for a number of independent scientific assessment and review activities related to the potential impacts of the proposed HLW repository at Yucca Mountain. In 1998, Nye County received funding for one of these activities, the EWDP. The EWDP is a drilling and characterization program designed to produce data regarding the geology, chemistry and hydrology of strata located in the potential flow path of groundwater emanating from Yucca Mountain and vicinity. However, Nye County views the EWDP as a wide-reaching groundwater contamination monitoring system and has several additional goals for study, such as characterization of the spring deposits at the southern end of Crater Flat. This means that many of the EWDP wells are located in areas that are not currently considered in DOE performance assessments as potential flow paths. To date, Nye County and DOE have cooperated extensively to allow DOE participation in EWDP activities, which has produced needed characterization data for the alluvium.

Originally developed as a three-year program, the EWDP is composed of three parts (Phases I, II and III) with one phase planned for each year from 1999 to 2001 (Nye County Department of Natural Resources and Federal Facilities, 2001b). The EWDP work plan originally called for construction of wells at 22 locations, with multiple wells at some of those locations (Nye County Nuclear Waste Repository Project Office, 1999). Budget constraints and changing priorities in drilling and characterization have resulted in modifications of the original plan, and (through Phase II) 22 wells have been drilled at 11 locations, with another 6 wells and well completions planned in Phase III. Existing and planned EWDP drill hole locations are shown in figure 1-1.

Nye County conducts various geophysical, geochemical, and hydrological testing under the EWDP. The location of wells, the extent of testing, and well construction are determined in advance and generally in consultation with other interested parties, such as the DOE and NRC. Where possible, all boreholes have been drilled using reverse-circulation rotary or hammer drilling methods with air as the drilling fluid. An exception includes Phase II drill hole NC–EWDP–2D in which bentonite mud was used because of the depth of the hole. Wells have generally been grouted and cased using 6-inch steel or smaller diameter PVC. Well casings include screened intervals to provide for groundwater sampling, and in three wells (NC–EWDP–1S, NC–EWDP–3S, and NC–EWDP–9S) Westbay MP 55 (Westbay Industries, Inc.) monitoring systems have been installed. The Westbay systems include packers for isolation of groundwater production zones. Wells NC–EWDP–1S, NC–EWDP–3S, and NC–EWDP–9S have two, three and four monitored zones, respectively. Two drill holes, NC–EWDP–19P and NC–EWDP–19D, are of particular interest because they comprise the ATC. In cooperation with Nye County, the DOE has been conducting a suite of hydrological and geochemical tests, including tracer studies, at the ATC. The ATC is expected to provide important

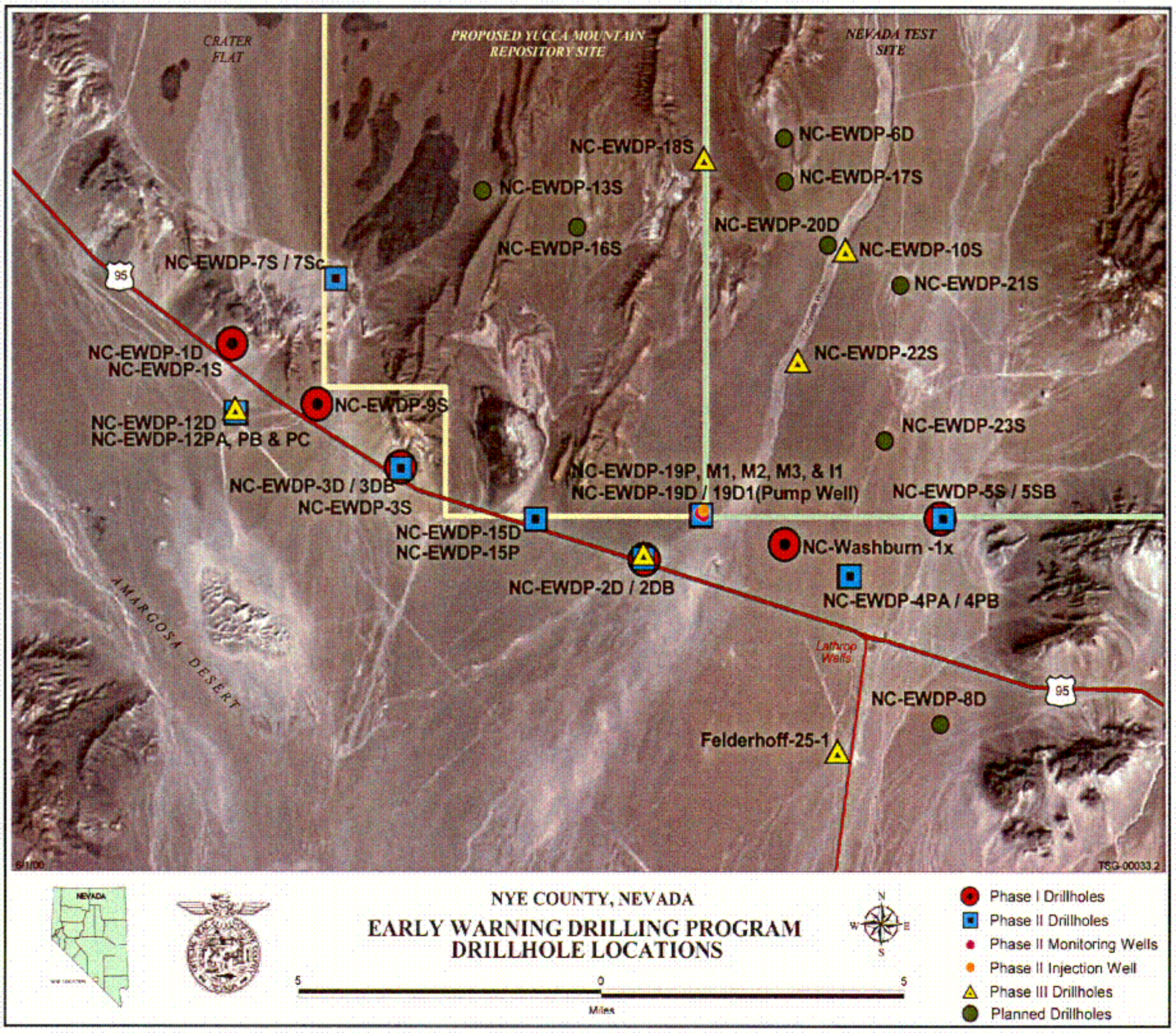

Figure 1-1. Map showing locations of current and planned Early Warning Drilling Program drill holes (Nye County Department of Natural Resources and Federal Facilities, 2001b).

information regarding the flow and transport characteristics of the alluvium (U.S. Department of Energy, 1999a,b; Nye County Nuclear Waste Repository Project Office, 1999). During Phase III of the EWDP, additional wells will be drilled in the vicinity of NC–EWDP–19D to facilitate cross-hole testing (U.S. Department of Energy, 1999b).

During construction of each drill hole, drill cuttings are collected and logged, and sample splits are provided to the DOE Sample Management Facility (SMF). The cuttings are used in analyses to determine lithology, mineralogy, and chemistry of strata within each drill hole. Additionally, first water and water in the well following achievement of the desired drilling depth are collected for chemical analyses. Following completion of the well, additional water samples are collected. As part of the EWDP operations plan, wells are periodically sampled for water chemistry. These sampling events are typically scheduled biannually. Several interested groups including Nye County, DOE and DOE contractors [e.g., U.S. Geological Survey (USGS) and Los Alamos National Laboratory (LANL) personnel], the State of Nevada, the University of Nevada Las Vegas (UNLV), and CNWRA, have participated in the biannual water sampling events.

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Nye County provides detailed descriptions of each borehole, including summary lithologic logs, cuttings logs, and other data regrading the EWDP at their website (Nye County Department of Natural Resources and Federal Facilities, 2001b). A summary data package is also available from Nye County that includes drilling logs, details on the completion of wells, information on the installation of monitoring systems and packers, results of pump tests, and geophysical survey results. Nye County has submitted an additional funding proposal to DOE for continuation of independent scientific and oversight studies beyond fiscal year 2001. Included in the proposal are plans for continuation of EWDP activities for five years (Nye County Department of Natural Resources and Federal Facilities, 2001a). These activities would include drilling of new holes, analyses of mineralogical and chemical data, geophysical logging, and flow characterization activities.

2 REPORT OBJECTIVES

Because the characterization activities associated with the EWDP are ongoing, and because the resources to assemble and analyze data and QA requirements for dissemination of data are extensive, there has been little formal presentation by Nye County or DOE of EWDP geochemical data. However, the current schedule for delivery of DOE's site recommendation for Yucca Mountain and the schedule required for review of a potential license application make timely access to EWDP data by NRC staff important. Whereas some of the data contained in this report are available from other sources, the data are generally not readily accessible and formatted for ease of use. Access for regulatory reviews is important because characterization of the alluvium in Fortymile Wash is a critical aspect of evaluating transport from the proposed repository. Further, characterization of the alluvium is important to several KTIs. For example, identification of mineralogy and stratigraphy within the EWDP drill holes may provide needed input for structural framework models of the region and may help to improve hydrologic models for the Fortymile Wash area (e.g., U.S. Nuclear Regulatory Commission, 2000b). Thus, dissemination of these data is important to support an integrated approach to evaluating DOE activities related to the potential repository.

The objective of this report is to provide a compilation of available geochemical data from the EWDP for comparative and interpretive use in NRC and CNWRA reviews of DOE characterization activities, and to support an independent approach to modeling and assessment of the potential performance of a Yucca Mountain repository. Consistent with this objective, this report contains little interpretation of the data contained within; however, a brief review of geochemical and mineralogical results is provided as a guide to areas where additional and more detailed work may be warranted.

This letter report includes

- Results of geochemical analyses of water samples collected from EWDP Phase I and II wells
  - Results from Nye County sampling and analyses through November, 2000
  - Results from sampling by DOE and DOE contractors (e.g., USGS, LANL) through 1999
  - Results of sampling by UNLV during May and November 1999
  - Results from sampling conducted by CNWRA during May and November 1999

- Mineralogical and geochemical analyses of selected well cutting samples from drill holes NC–EWDP–02D and NC–Washburn–1X (figure 1-1)
  - X-ray diffraction patterns and peaks for selected samples
  - Results of x-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS) analyses for selected samples
  - Photomicrographs from thin sections of selected samples

Selected data are presented in tables and figures within the body of this report. All available data are provided in electronic format on the included CD. Appendix A describes data file content, format, and labeling in detail.

3 METHODOLOGY FOR SAMPLE COLLECTION AND ANALYSES

3.1 EARLY WARNING DRILLING PROGRAM WATER SAMPLES

CNWRA personnel participated in the biannual Nye County EWDP sampling events in May and November of 1999. The purpose of CNWRA participation was to observe practices and procedures used by EWDP to collect water samples and to obtain water samples for independent chemical analyses. Depending on the sampling protocol used to obtain a representative water sample from each well, only one or two EWDP wells were sampled per day during the sampling events. EWDP scheduling constraints therefore limited the number of samples collected by CNWRA during each sampling trip. Water samples were collected from wells NC–EWDP–01S, NC–EWDP–09S, and NC–EWDP–03S (figure 1-1).

Well NC–EWDP–01S was completed in March 1999. It was drilled to a total depth of 340 ft and its casing extends to about 290 ft. According to Nye County information, two groundwater zones, one in the valley-fill alluvial deposits and one in the upper tertiary volcanic sequence, were selected for long term monitoring (Nye County Department of Natural Resources and Federal Facilities, 2001b). The two groundwater monitoring zones are screened intervals at 160–180 ft and 210–270 ft. Based on the summary lithologic log both zones appear to be located in welded tuff sequences. The shallow zone (160–180 ft) screen spans a dense welded tuff that is light grey-brown-orange in color and is very near the contact between the tuff and the overlying valley-fill alluvium. The deeper zone (210–270 ft) screen spans a darker, calcareous tuff with higher water yield. This zone produces water with a milky appearance.

Well NC–EWDP–09S was drilled to a depth of 397 ft and completed in January 1999, and a Westbay MP–55 system was installed in March 1999. This well has four groundwater monitoring zones and is screened at the 90–120, 140–160, 250–290, and 330–340 ft intervals. The upper two zones are within the valley-fill alluvial sequence. The zone located at 250–290 ft has been interpreted to span the contact between the valley-fill and the underlying Tertiary volcanic rock, while the lowermost zone is within the Tertiary volcanic sequence.

Well NC–EWDP–03S was completed in March 1999. It was drilled to a total depth of ~550 ft and is cased with 6-in steel to about 295 ft; below 295 ft it is an open borehole. The steel casing is slotted between depths 250 and 270 ft. A PVC-cased Westbay MP–55 system is installed within the well and extends to a depth of ~526 ft. The Westbay system has three zones packed-off for groundwater monitoring. Zone 1 is packed from ~244–270 ft with a pumping port at 265 ft; Zone 2 is packed from 335–420 ft with a pumping port at 408 ft; and Zone 3 is packed from 474 ft to the bottom of the borehole with a pumping port at 500 ft. All three zones appear to be located in tuff sequences, based on Nye County's lithologic logs (Nye County Department of Natural Resources and Federal Facilities, 2001b). Water from NC–EWDP–03S is of interest because it has been used by DOE in early studies of radionuclide sorption onto alluvial material.

To withdraw water samples from wells in which the Westbay systems are installed, the *in situ* pressure monitoring tools for the system must first be removed followed by use of a separate tool, which is lowered into the well bore to open the sampling port for the zone of interest (some details of the Westbay system can be found in Bertetti (1999). Following opening of the sampling port, the tool is removed and water level measurements are monitored in an effort to confirm the open status of the port. Once the port is confirmed open and the water level has stabilized, water level measurements are taken by interested parties (usually Nye County and USGS) using a conductivity probe and steel tape. After water level measurements are complete, a stainless steel, air-driven pump (Bennett Sample Pumps, Amarillo, TX) is lowered down hole to begin the purge/sampling process. The Bennett pump is used for sampling at all wells.

Wells are typically purged before and during sampling at ~1 to 1.5 gallons per minute. The amount of purge time required depends on the procedure used to determine adequate purge volume. In early sampling events, purge volumes were determined by calculation using the guidelines of Koterba et al. (1995) and drill hole and sample zone dimensions. Because of the resulting long purge times, later sampling events used alternative purge protocols based on stabilization of chemical parameters of the purged water. Continuous measurement of purge water was accomplished with an in-line probe assembly, which measured pH, specific conductivity, and oxidation-reduction potential (ORP). In general, pH increased, conductivity decreased, and ORP increased during the purging process. Each interested group collected water samples after the minimum purge volume or appropriate chemical stabilization of all measured parameters had been achieved. All samples were collected from the same discharge point. The volume and type of container used for the collection of samples varied depending on the needs and interests of the samplers.

CNWRA field analyses included measurement of temperature, pH, ORP, conductivity, turbidity, and alkalinity. Temperature, pH, conductivity, ORP, alkalinity, and turbidity measurements were made immediately after collection of water. Alkalinity was determined by titration to an end point pH of 4.5. Collected water was filtered using a pre-cleaned 0.45 µm filter and preserved as required for subsequent chemical analyses. Major cations and metals were determined using ICP atomic emission spectroscopy (AES), while anions were determined using ion chromatography.

Analyses by other groups is accomplished using various methods. Alkalinity, pH, temperature, ORP, dissolved oxygen, specific conductivity are measured in the field. Additional analyses are conducted based on the needs of the investigating group, and methods are often included in the published data files. Where available, this information is retained in the data files accompanying this report.

3.2 MINERALOGIC AND PETROGRAPHIC ANALYSIS OF EARLY WARNING DRILLING PROGRAM WELL CUTTINGS

At the request of NRC staff, well cuttings from drill holes NC–EWDP–02D, NC–EWDP–05S, and NC–Washburn–1X were obtained from the DOE SMF in early 2000. These cutting samples were collected by Nye County and DOE during well construction. As mentioned previously, all three holes were drilled using a reverse-circulation air rotary method and any variation in drilling fluid composition, such as addition of water to reduce dust load, are recorded in the well cutting logs (Nye County Department of Natural Resources and Federal Facilities, 2001b). Because of their location within the potential flow path from Yucca Mountain (Civilian Radioactive Waste Management System Management and Operating Contractor, 2000b) the NC–EWDP–02D and NC–Washburn–1X cuttings were initially selected for detailed analysis. Each drill hole was represented by cuttings collected from approximately 5-ft intervals throughout the entire depth of the drill hole. Samples of the cuttings were selected for analysis based on several considerations including: location with respect to observed water table within the drill hole, changes in color or lithology as indicated by the cuttings, location with respect to identified lithology in the summary lithologic log for the drill hole (Nye County Department of Natural Resources and Federal Facilities, 2001b), and location of water producing zones as indicated on the cuttings sample log (Nye County Department of Natural Resources and Federal Facilities, 2001b). Figure 3-1 depicts the location of and type of analysis for cuttings samples selected for study, and appendix B provides details of all cuttings for NC–EWDP–02D and NC–Washburn–1X, including analyzed samples.

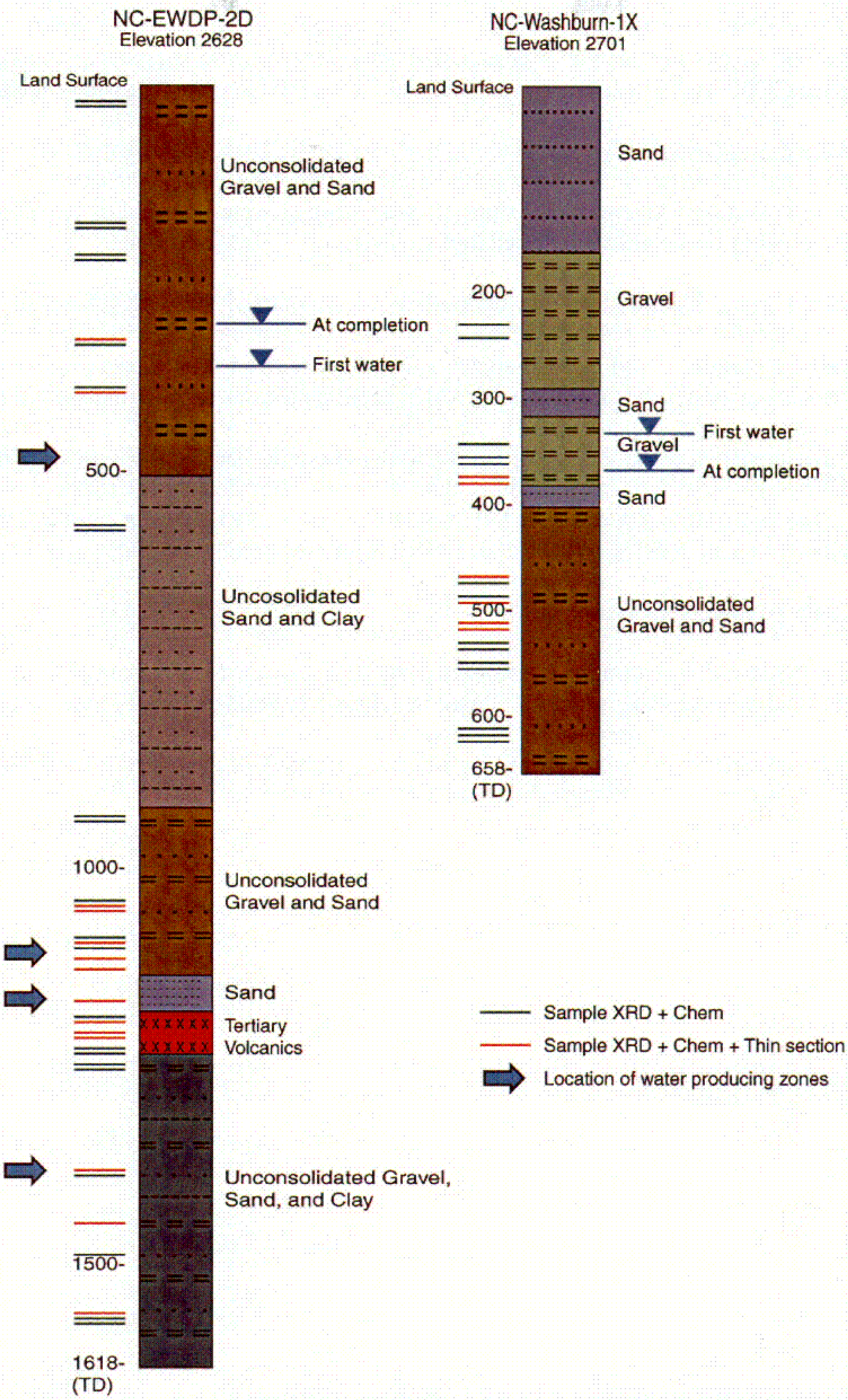

Figure 3-1. Approximate locations of cuttings samples from NC–EWDP–02D and NC–Washburn–1X selected for detailed analyses. Water producing zones are simple references to flow during drilling as recorded in cuttings logs (Nye County Department of Natural Resources and Federal Facilities, 2001b)

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The selected cuttings samples were prepared for mineralogic, petrographic, and chemical analysis by first quartering the cuttings sample. A portion (~10 g) of the quartered sample was transferred to a ball mixer-mill (Spex 8000) and powdered. The powder was further split into approximately equal fractions for analysis by x-ray diffraction (XRD) and XRF/ICP-MS. Some cuttings samples contained individual mineral grains that were distinct in appearance from the bulk of the sample. These individual grains were segregated and also powdered for analysis. A subset of the cuttings samples selected for chemical analyses was identified for thin sections. Macroscopic grains of these samples were prepared by Mineral Optics, Inc. (Wilder, VT) as epoxy impregnated, polished thin sections.

Minerals were identified in powders using an automated (RADIX) Siemens D500 x-ray diffractometer (Cu tube, Ni filter, 40 kV, 37 mA; scan range 5–70° at 0.1° step size; count time 5 sec). The graphics interface program JADE (Materials Data Inc., Livermore, CA) was used to create and output diffraction patterns of the absolute intensity of the diffraction signal at each 0.1° 2-theta angle. Peak analyses of diffraction patterns were conducted with the JADE peak finding algorithm. Identification of mineral phases was accomplished using the JADE Search/Match module. The Search/Match module compares generated diffraction patterns to mineral diffraction databases provided by the International Centre for Diffraction Data [International Centre for Diffraction Databases 1993; Powder Diffraction File PDF-2 Database Sets 1–43 and NIST Crystal Data (1993)]. Analyses of textural properties and mineralogic relationships were conducted by examination of standard polished thin sections using a Nikon Optiphot-Pol transmitted light petrographic microscope.

The chemistry of the cuttings was analyzed using XRF and ICP-MS (Washington State University). Details of the analytical procedures can be found in Johnson et al. (1999) and at the Washington State University GeoAnalytical Lab web site (Washington State University, 2001). Standard reference materials were included with well cuttings samples to provide a comparison of analytical accuracy and precision. Results are provided in the data files for XRF and ICP-MS analyses.

4 RESULTS AND DISCUSSION

Although the primary focus of this report is to provide a collection of data files for subsequent use in geochemical and mineralogic analyses of the saturated alluvium, a brief summary of results is presented here. It is expected that additional detailed work with the data contained herein will form the basis for more definitive conclusions.

4.1 EARLY WARNING DRILLING PROGRAM WATER ANALYSES

A comparison of CNWRA, Nye County, and DOE analytical results for wells NC–EWDP–01S, NC–EWDP–03S, and NC–EWDP–09S is shown in table 4-1. The results are consistent with each other, which provides some confirmation of their accuracy, and indicates that DOE results may be appropriate for inclusion into performance assessment models. Detection limits vary depending on the method used for the analysis and the element of interest. When provided by the originating source, detection limits are included in the data files. Comparison between different sampling events is required to determine if chemistry results from any one well are consistent over time.

All available DOE and Nye County EWDP water sample results, including some samples collected from regional wells not explicitly within the EWDP (e.g., BGMW #13), are plotted in figure 4-1. The sampled waters separate into at least three distinct populations. One group with a dominant Na-HCO_3 composition, another with a Ca-SO_4 signature, and third group that is intermediate in composition. A few outliers are also noted, but these are generally associated with bailed first-water, which likely contains more sediment and is not necessarily representative of the undisturbed chemistry of water in the well. The same data are plotted as a Ludwig-Langelier diagram in figure 4-2. The Ludwig-Langelier diagram seems to better separate the distinct clusters of EWDP waters. It should be noted that several of the samples that do not fit into one of three clusters are from the western area of Fortymile Wash (e.g., NC–EWDP–4PA and 5S) and have a SO_4+Cl content of at least 20 percent. Representative compositions of waters from EWDP wells are plotted with waters from other surrounding and reference wells in figure 4-3. A review of all figures reveals that waters from wells NC–EWDP–01S, 01D, 07S, and 12P are closely related. Likewise, waters from NC–EWDP–03S, 03D, and other alluvial wells (e.g., 5S) are similar. The waters from NC–EWDP–09S tend to be in between. It is notable that there appears to be a separation of water chemistry from NC–EWDP–19P and 19D; however, the well 19 results are based on a limited number of samples (1 each).

Review of minor and trace elements (as well as isotopic compositions) may offer additional insight regarding well chemistry and flow paths. Two elements that vary between wells are Li and Sr. When plotted versus Na concentration in figure 4-4, the differences between waters from NC–EWDP–01D/S, 03D/S, and 09S become apparent. Unfortunately, because of the similarity in source materials that make up the saturated alluvium, the general chemistry of the well waters may be of limited use in determining origin of flow and flow paths within the system. Understanding these flow paths may depend in part on wells that are effectively screened with respect to depth. Currently, of wells within the predicted flow path from Yucca Mountain, only NC–EWDP–19D is screened at several depth intervals.

Table 4-1. Results of sampling and analyses conducted by Center for Nuclear Waste Regulatory Analyses, U.S. Department of Energy (U.S. Geological Survey), and Nye County for several Early Warning Drilling Program wells. For convenience of comparison, only a subset of the total number of parameters analyzed for wells is shown. The complete data sets are available in the attached files.

	NC-EWDP-01S Zone 2 May 17, 1999			NC-EWDP-09S Zone 4 May 18, 1999			NC-EWDP-03S Zone 2 Nov 15, 1999		
Parameter	**CNWRA**	**DOE (USGS)**	**Nye Co.**	**CNWRA**	**DOE (USGS)**	**Nye Co.**	**CNWRA**	**DOE (USGS)**	**Nye Co.**
Temp. (°C)	28.6	28.3	28.3	28.5	28.8	30.6	29.6	31.8	31.6
pH	7.40	7.3	7.4	8.03	7.9	7.9	8.61	8.5	8.9
Spec. Cond. (mS/cm)	836	819	811	489	493	480	557	524	665
Ca (mg/L)	60.8	55	59.4	20	19	19.8	0.79	0.72	0.79
Mg (mg/L)	32.4	29	31.3	7.81	7.4	7.64	0.143	0.08	0.08
Na (mg/L)	74.3	62	69.4	77.2	74	75.3	123	120	132
K (mg/L)	10.7	9.4	9.55	4.32	4	4.11	3.83	3.3	3.45
SO_4 (mg/L)	128	127	134	60.5	59	62.6	50	47	43.8
Cl (mg/L)	16.9	16	16.7	10.5	10	10.6	***	12	12.8
SiO_2 (aq) (mg/L)	54.7	48	56.8	50.9	49	43.3	58.6	57	52
Ba (mg/L)	34.5	35	31.8	<5	5	4	<5	<1	***
Li (mg/L)	73	66	66.5	80	81	80.2	161	169	***
Mn (mg/L)	53	52	48.6	6	5	5.2	7	2	***
Sr (mg/L)	628	507	505	162	141	138	<5	3	***

***Not determined

4.2 EARLY WARNING DRILLING PROGRAM CUTTINGS MINERALOGICAL ANALYSES

Alluvium from the Nye County boreholes is epiclastic or sedimentary in nature (i.e., it was formed at the surface by weathering, erosion, transport, and deposition of fragments of pre-existing rock). The well cuttings are disturbed samples of these original epiclastic rocks. During the drilling process the loosely consolidated alluvium is disaggregated (i.e., separated into its component parts) and the cements and matrix holding rock fragments together are typically totally or partially removed. Components of the alluvium consist predominantly of volcanic rock fragments, quartz, and feldspar (figures 4-5 and 4-6). Optical and XRD analyses indicate that feldspars consist of plagioclase and sanidine (figure 4-7). Mafic minerals such as biotite and hornblende are sparse to absent. The volcanic rock fragments generally have a microcrystalline or glassy groundmass. Based on these mineralogic and textural characteristics the source rocks for the alluvium consist predominantly of aphanitic calc-alkaline volcanic tuffs (e.g., rhyolites, rhyodacites, and dacites).

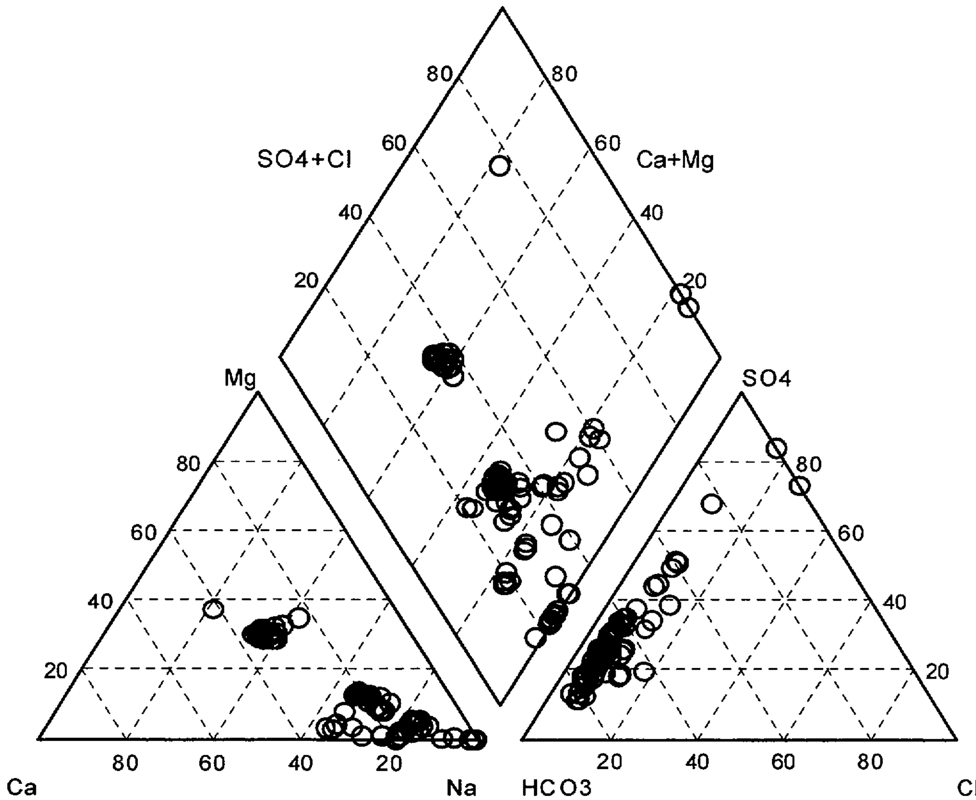

Figure 4-1. Piper diagram of available Nye County, U.S. Department of Energy and U.S. Geological Survey results for Early Warning Drilling Program wells. Early Warning Drilling Program water chemistries appear to group into at least three distinct population.

Volcanic rock fragments are texturally varied, indicating that the alluvium was derived from several source volcanic formations. Textures include aphanitic, porphyritic, pumiceous, and variolitic. Volcanic rock fragments with aphanitic and porphyritic textures are most common; pumiceous and variolitic textures are less common. Volcanic rock fragments with an aphanitic texture are generally comprised of small birefringent microlites of euhedral feldspar that are intergrown in an irregular fashion (figures 4-5 and 4-6). Often the microlites are disposed in a subparallel manner as a result of flow of the magma. Porphyritic volcanic rock fragments consist of phenocrysts of quartz and feldspar in an aphanitic groundmass (figures 4-5, 4-6, and 4-8). Volcanic rock fragments composed of highly vesicular glass have a pumiceous texture (figures 4-9). Pumiceous volcanic rock fragments in the alluvium have vesicles that are elongate due to stretching of the glass during flow. The vesicles are generally filled by quartz or other silica phases (e.g., opal or cristobalite) which are products of glass alteration. Volcanic rock fragments with variolitic texture are composed of laths of feldspar in a glassy groundmass (figures 4-5 and 4-6).

Sedimentary rocks and plutonic rocks in the alluvial source area provide additional but minor components for the alluvium. Sandstone fragments are the most common sedimentary rock fragments and consist of rounded to subrounded quartz grains cemented by fine-crystalline calcite and/or dolomite (figures 4-10). Volcanic rock fragments having a plutonic origin consist of quartz crystals with a fine phaneritic, equigranular fabric (figure 4-11).

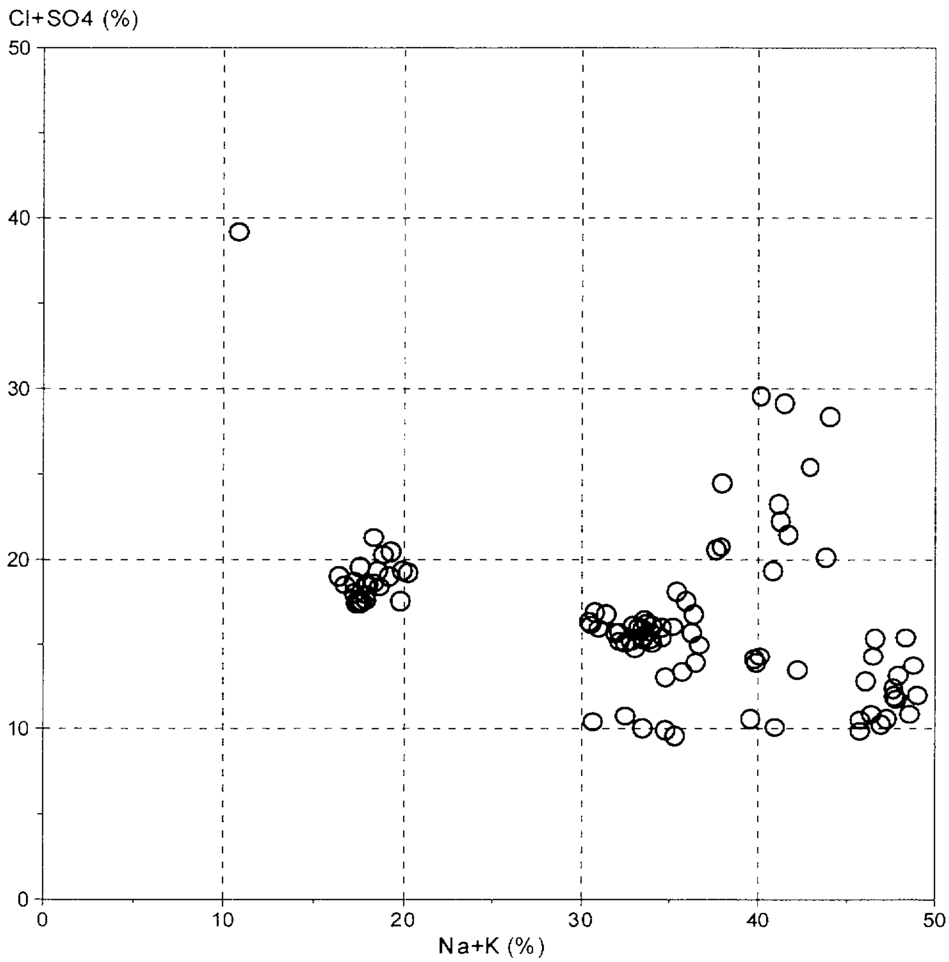

Figure 4-2. Ludwig-Langelier plot of available Nye County, U.S. Department of Energy and U.S. Geological Survey geochemical results from Early Warning Drilling Program wells. Early Warning Drilling Program water chemistries tend to cluster in at least three distinct populations.

As mentioned previously, drilling of the alluvium has resulted in disaggregation of the original epiclastic rock. However, the well cuttings do include some epiclastic fragments that may represent the alluvium as it existed before disaggregation. These epiclastic particles consist of volcanic rock fragments, quartz, and feldspar cemented or held together by silt-sized particles (predominantly feldspar) (figure 4-12). The cement/matrix is generally very porous. In addition, individual quartz and feldspar grains and volcanic rock fragments are often rimmed by cement/matrix consisting of silt-sized feldspar particles (figure 4-9).

At a depth of about 1,125 ft in borehole NC–EWDP–02D, optical examination and XRD analysis indicates the presence of dolomite in the well cutting samples (figure 4-13). Thin section examination indicates the occurrence of dolomite fragments and dolomite cement at and below this depth in the borehole (figures 4-14 and 4-15). The fragments and cement are composed of microcrystalline dolomite. Textural relationships indicate that the dolomite is a replacement after feldspar. For example, microcrystalline feldspar

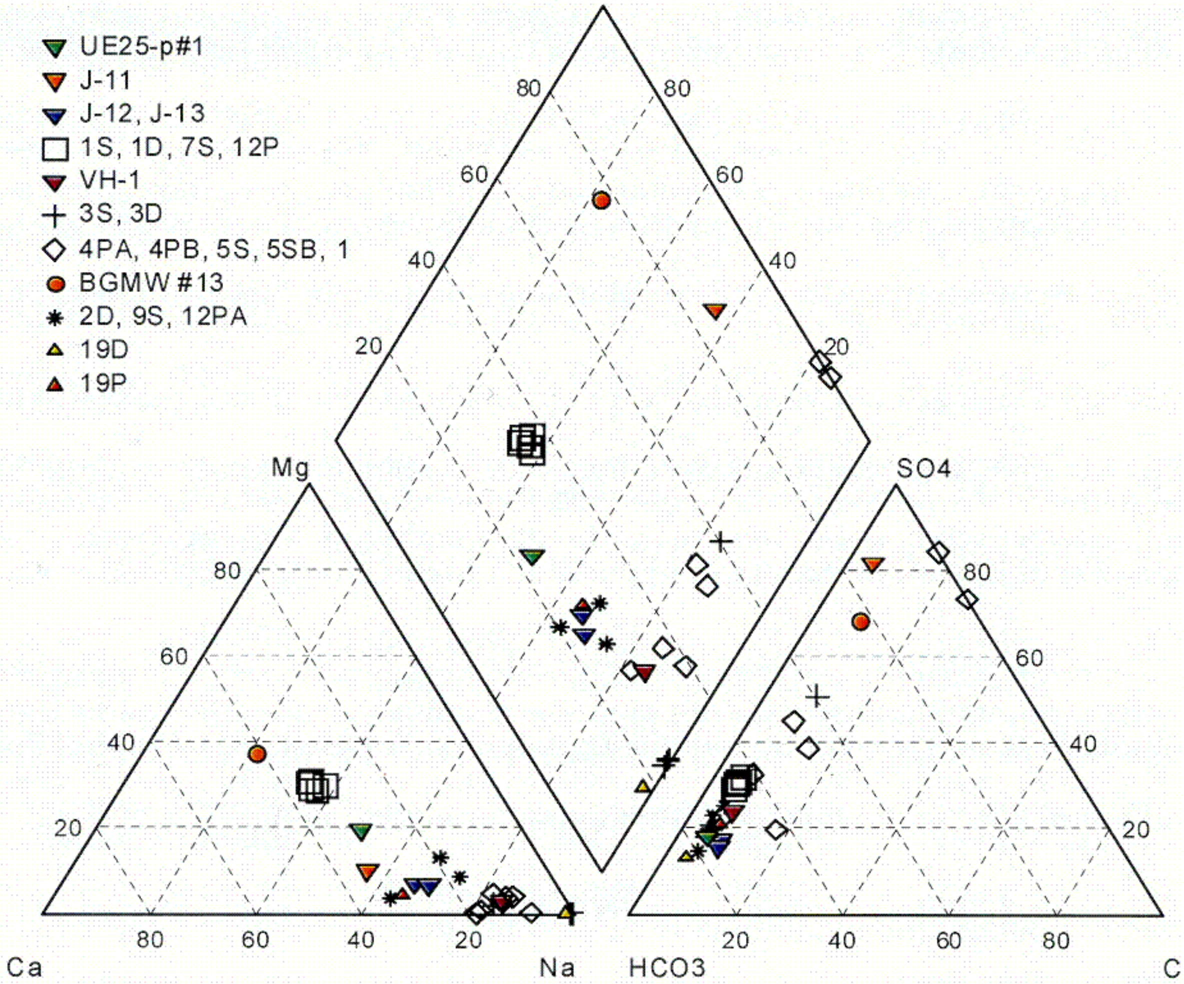

Figure 4-3. Piper diagram of representative chemistries from Early Warning Drilling Program wells shown with chemistries of waters from other wells in the surrounding region. Note that the chemistry of alluvial wells (e.g., 19 D/S and 5S) is distinct from chemistry of wells associated with Crater Flat (e.g., 7S).

composing volcanic rock fragments, individual feldspar crystals, and feldspar phenocrysts in volcanic rock fragments are often observed to be partially or totally replaced by microcrystalline dolomite (figure 4-16). The dolomite cement is likely a replacement of the silt-sized particles of feldspar which cemented components of the alluvium and survived disaggregation due to drilling.

Optical examination and XRD analyses of samples from a depth of about 1,195 ft, indicates the presence of calcite in borehole NC–EWDP–02D (figure 4-17). The calcite occurs as fragments in the alluvium or as open space fillings in volcanic rock fragments (figure 4-18). The calcite commonly has a sparry texture consisting of fine- to medium-sized, equigranular, interlocking crystals. In general, calcite abundance increases with depth in borehole NC–EWDP–02D. Locations of significant calcite occurrence within the alluvium are important given that calcite may play a significant role in the retardation of Np, an important contributor to dose at long time frames (Bertetti, 2001). Textural relationships indicate that the

C03

calcite is a replacement after feldspar. For example, feldspar phenocrysts in volcanic rock fragments are often partially or totally replaced by calcite (figure 4-19). In addition, replacement of feldspar crystals by calcite can sometimes be determined by preservation of feldspar twinning in the calcite (figure 4-20).

The zeolite mineral clinoptilolite is a minor but ubiquitous component of the alluvium. XRD analyses indicate that clinoptilolite is most common in borehole NC–EWDP–02D at depths ranging from 925 to 1,060 ft (figure 4-21). Clinoptilolite generally forms as a devitrification product of volcanic glass or as an alteration product of aluminosilicates such as feldspars. Due to the fine crystalline nature of the alluvium components, clinoptilolite is difficult to identify optically in most samples. However, in a few samples clinoptilolite has been observed filling open space left by dissolution of feldspar phenocrysts in volcanic rock fragments (figure 4-22).

Plots of major and trace element of chemistry (derived from XRF analyses) with respect to depth in drill hole NC-EWDP–02D appear to be consistent with the observed occurrence of calcite and dolomite (figures 4-23 and 4-24). Calcium concentrations (figure 4-23), as well as Ba concentrations (figure 4-24) increase below 1,125 ft coincident with appearance of dolomite and calcite. Changes in *K* are associated with noted changes in lithology (tertiary volcanics) near the 1,200 ft depth (figure 4-23). An increase in the Sr concentration of samples near the 1,060 ft depth may be associated with the observed occurrence of clinoptilolite at that depth (figure 4-24).

A plot of rare earth element (REE) concentrations, as determined by ICP-MS and normalized to C1 chondrite values (Anders and Grevasse, 1989) reveals the similarities between samples from the Tertiary volcanics and differences between those samples and a sample of alluvium from near the 400 ft depth of well NC–EWDP–02D (figure 4-25). The Tertiary volcanic samples appear to have a sharper negative Eu anomaly and a Ce anomaly that is opposite that exhibited by the alluvium sample.

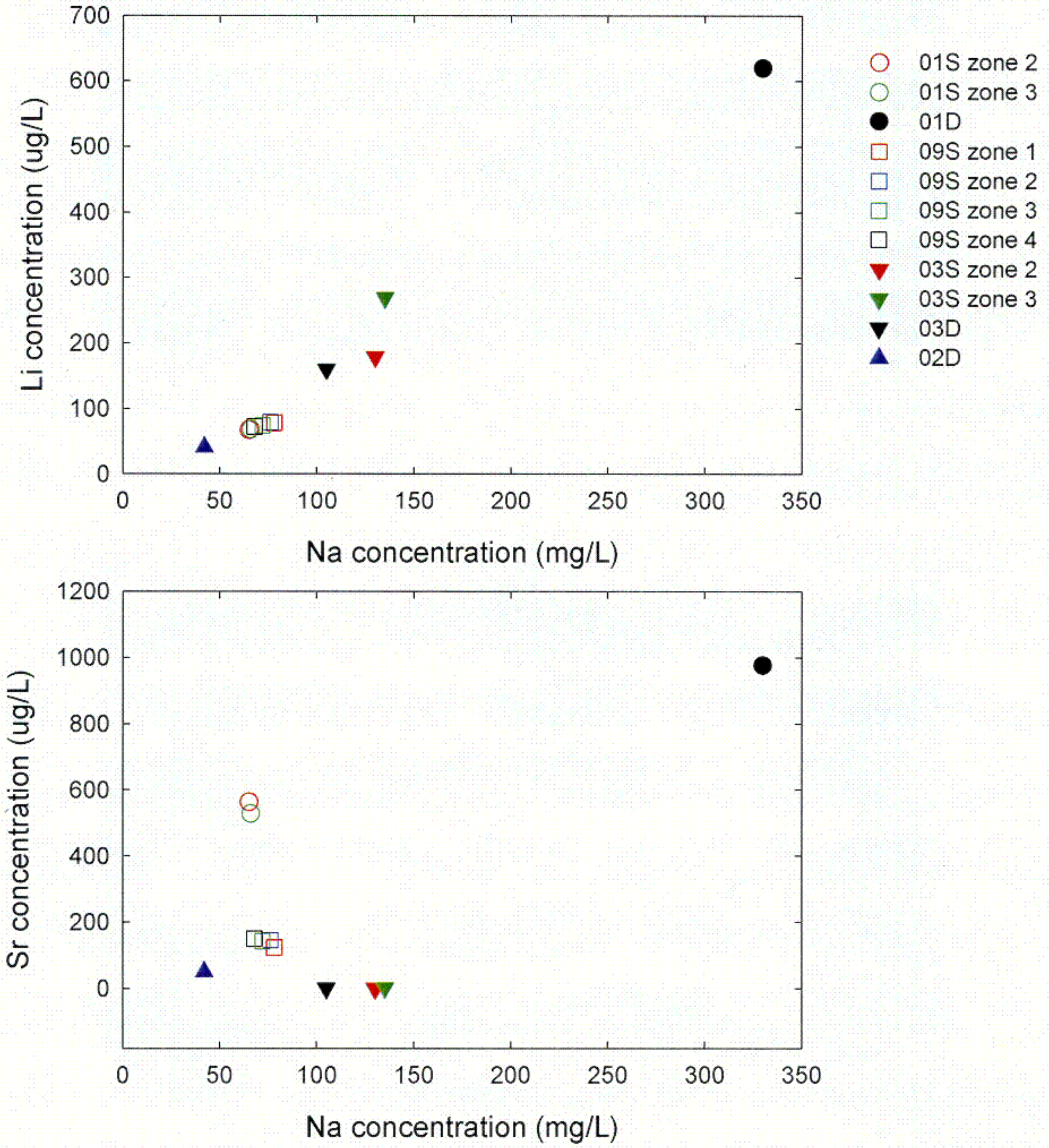

Figure 4-4. Plots of Li and Sr concentrations versus Na concentrations for selected Early Warning Drilling Program wells. Comparison of Li and Sr behavior may reveal differences between well waters and their origin.

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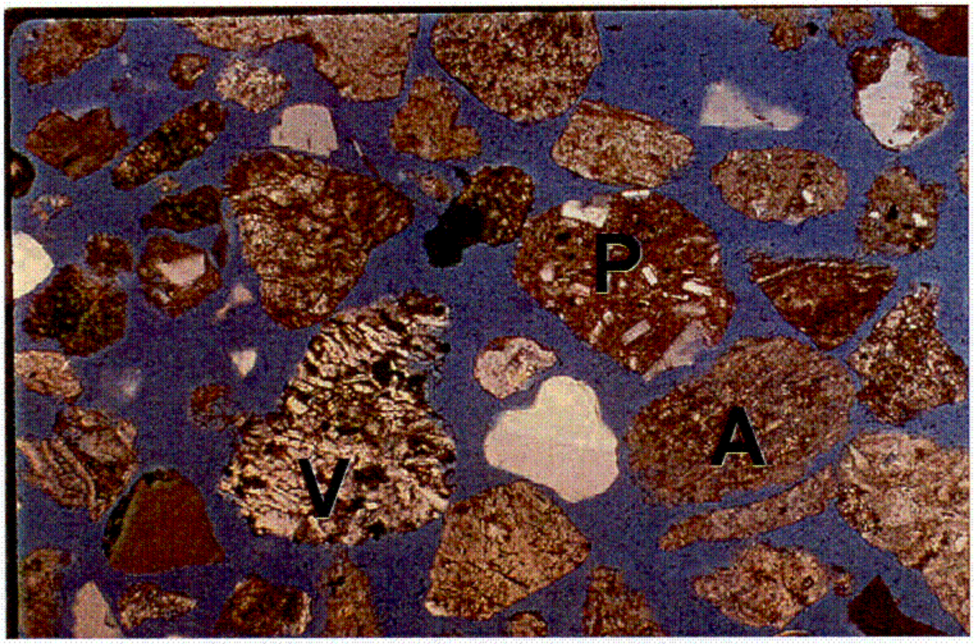

Figure 4-5. Photomicrograph of well cuttings of alluvium from boreholes NC–EWDP–02D taken at a depth of 1,045 to 1,050 ft. The alluvium consists of volcanic rock fragments quartz, and feldspar. Volcanic rock fragments show a variety of textures including aphanitic (A), porphyritic (P) and variolitic (V). Figure is 2.6 mm across.

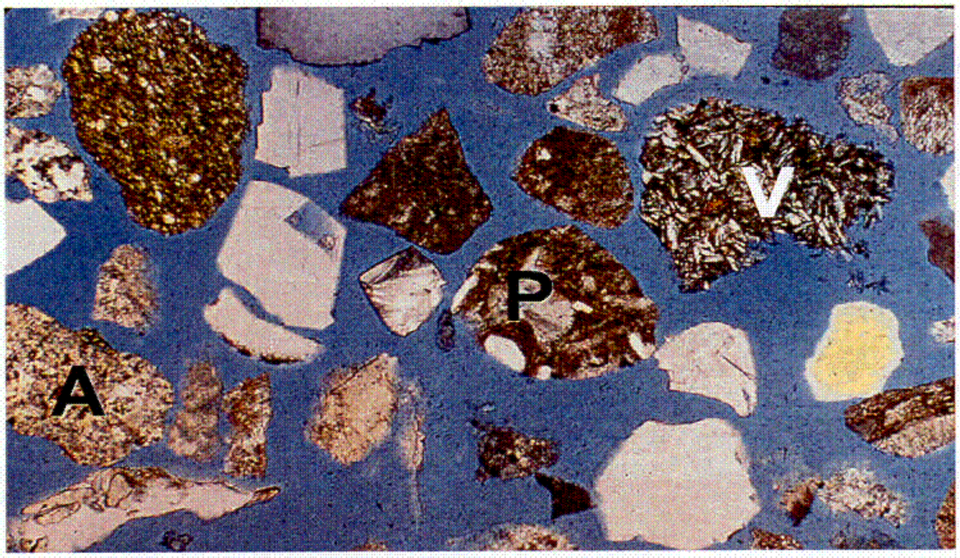

Figure 4-6. Photomicrograph of well cuttings of alluvium from borehole NC–Washburn–1X taken at a depth of 525 to 530 ft. The alluvium is composed of volcanic rock fragments with varying textures aphanitic (A), porphyritic (P), variolitic (V), and quartz and feldspar. Figure is 2.6 mm across.

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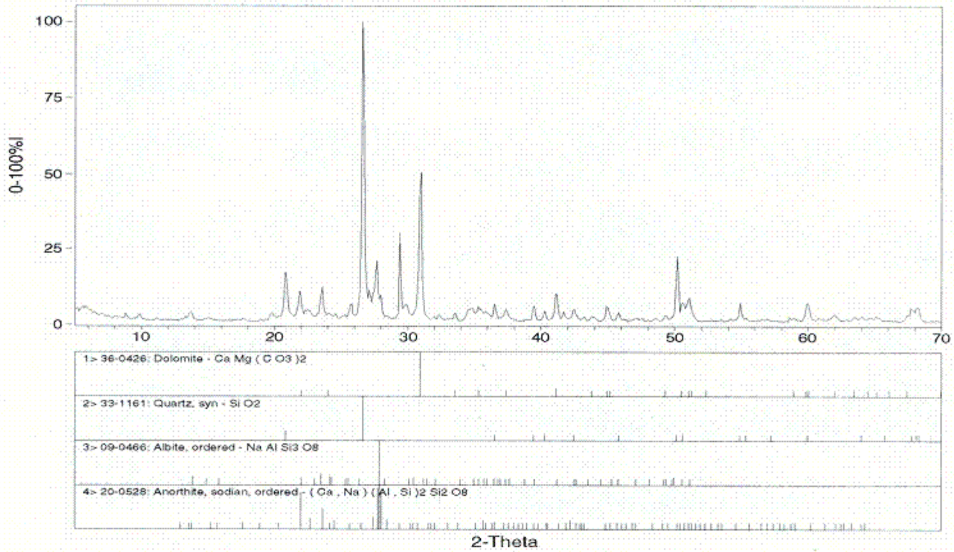

Figure 4-7. X-ray diffraction pattern of well cuttings of alluvium taken from borehole NC–EWDP–02D at a depth of 330 to 335 ft. Mineralogic components of the alluvium include quartz, albite, anorthite, and sanidine.

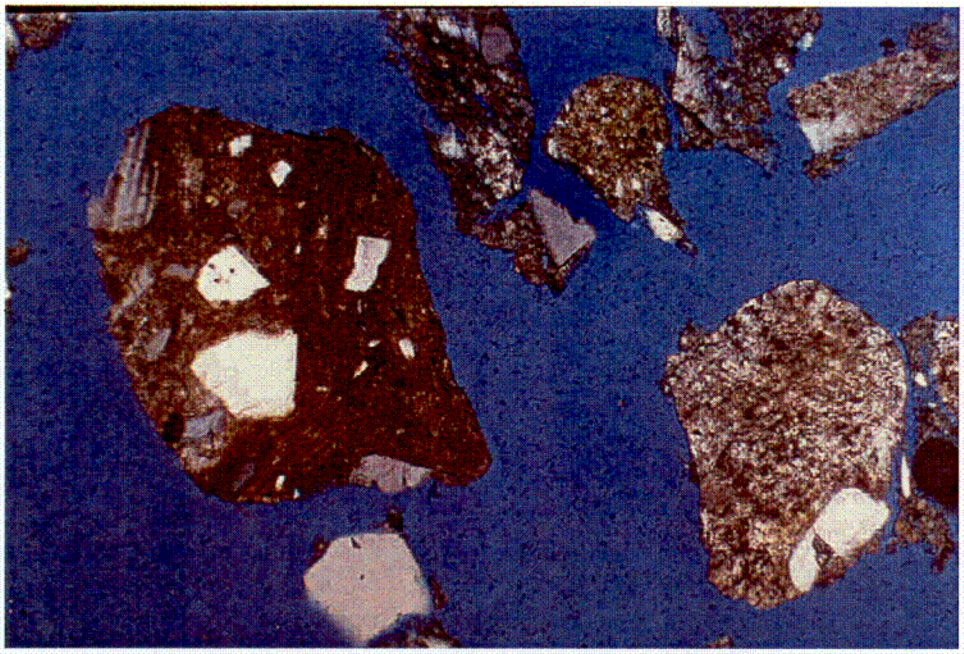

Figure 4-8. Photomicrograph of volcanic rock fragments from borehole NC–EWDP–02D taken at a depth of 330 to 335 ft. Several of the volcanic rock fragments in this photo display a porphyritic texture consisting of phenocrysts of quarts and feldspar in an aphanitic groundmass. Figure is 2.6 mm across.

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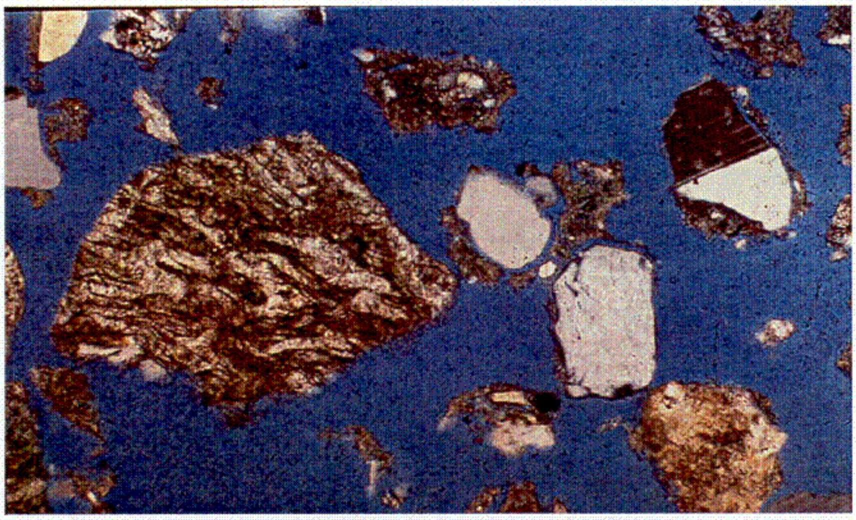

Figure 4-9. Photomicrograph of well cuttings of alluvium from borehole NC–EWDP–02D taken at a depth of 330 to 335 ft. The volcanic rock fragment at the left center of the photo has a pumiceous texture. The vesicles in the volcanic rock fragment are elongate due to stretching of glass during flow of the gas-charge magma and have been filled by silica phases (e.g., opal). Also notice the silt-sized particles (predominantly feldspars) that rim quartz and feldspar crystals at the right center of the photo. These silt-sized particles may represent the original alluvial cement which existed before disaggregation. Figure is 2.6 mm across.

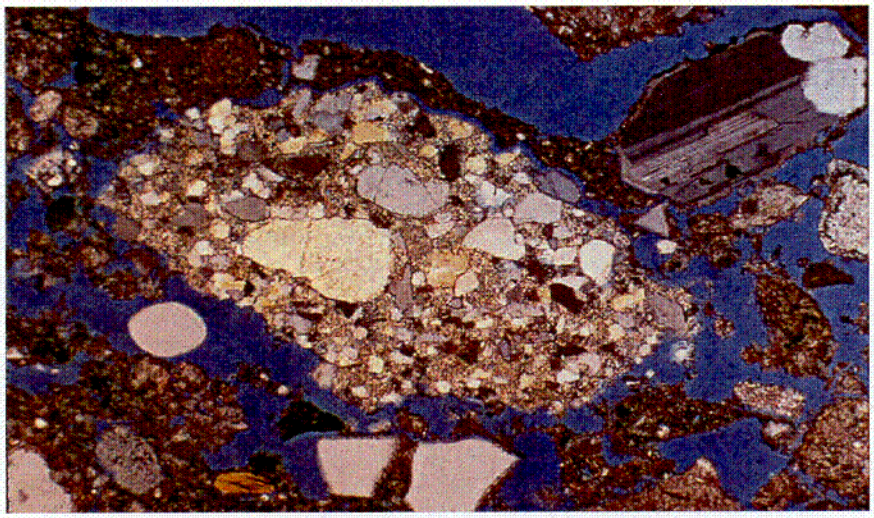

Figure 4-10. Photomicrograph of a sandstone fragment in the alluvium taken from borehole NC–EWDP–02D at a depth of 1,555 to 1,560 ft. The sandstone fragment consists of quartz grains cemented by fine-crystalline calcite. The dark, fine-crystalline material surrounding the sandstone fragment and other components of the alluvium is dolomite. The dolomite is likely a replacement of silt-sized feldspar particles that originally cemented components of the alluvium. Figure is 2.6 mm across.

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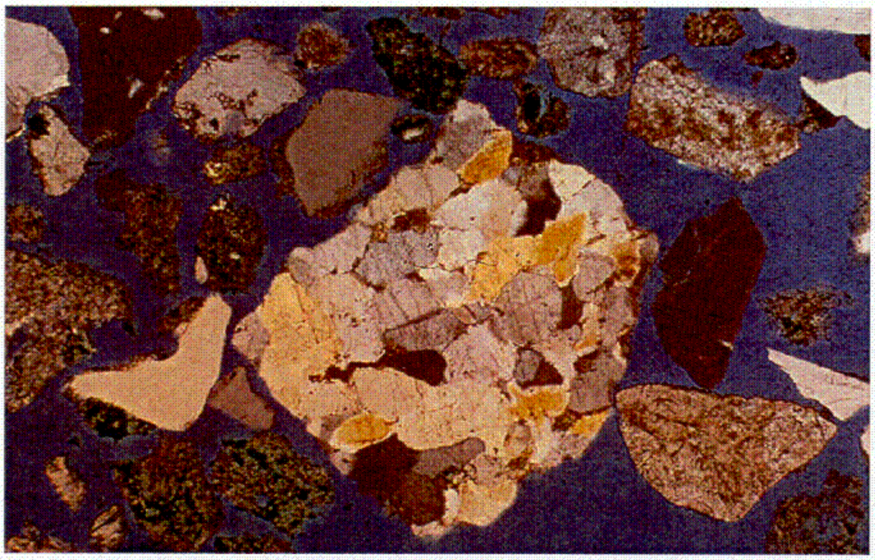

Figure 4-11. Photomic4rograph of well cuttings of alluvium from borehole NC–EWDP–02D taken at a depth of 1,215 to 1,220 ft. The volcanic rock fragment in the center of the photo consists of interlocking, equigranular quartz and was probably derived from a plutonic (e.g., granitic) source. Figure is 2.6 mm across.

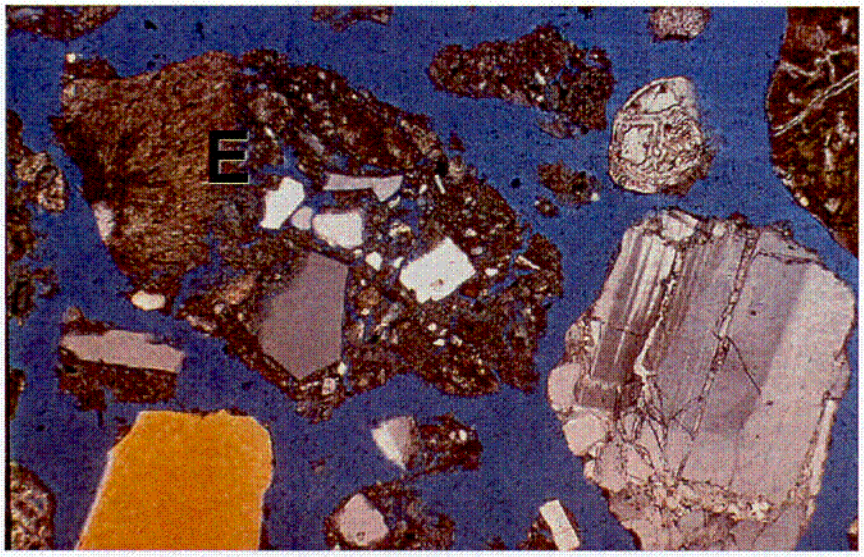

Figure 4-12. Photomicrograph of well cuttings of alluvium from borehole NC–EWDP–02D taken at a depth of 395 to 400 ft. An epiclastic rock fragment (E) consisting of quartz, feldspar, and volcanic rock fragments cemented by silt-sized feldspar particles is shown at the top left of this photo. The epiclastic fragment may represent the alluvium as it existed before disaggregation. Figure is 2.6 mm across.

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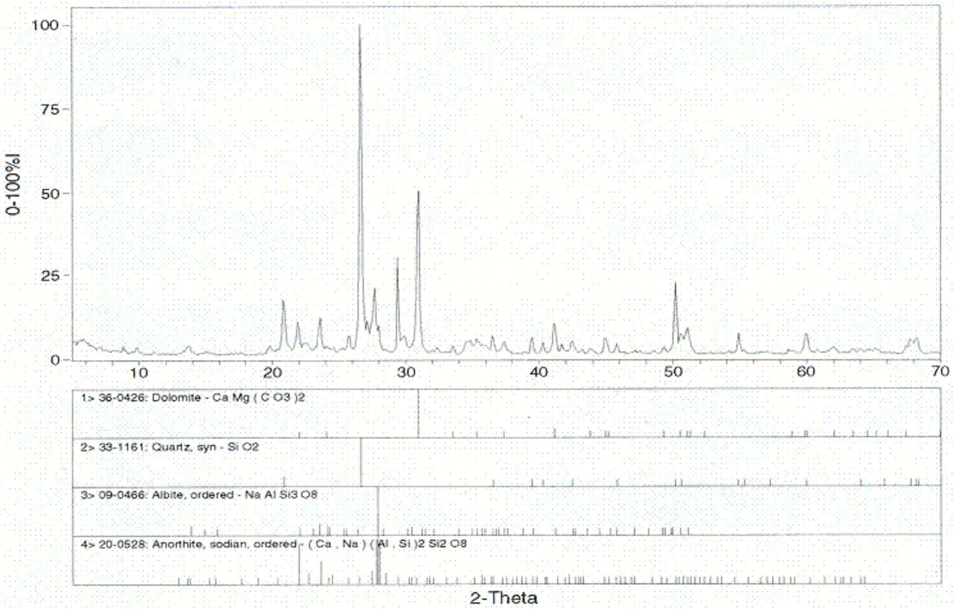

Figure 4-13. X-ray diffraction pattern of well cuttings of alluvium from borehole NC–EWDP–02D taken at a depth of 1,165 to 1,170 ft. Components of the alluvium include dolomite, quartz, albite, and anorthite.

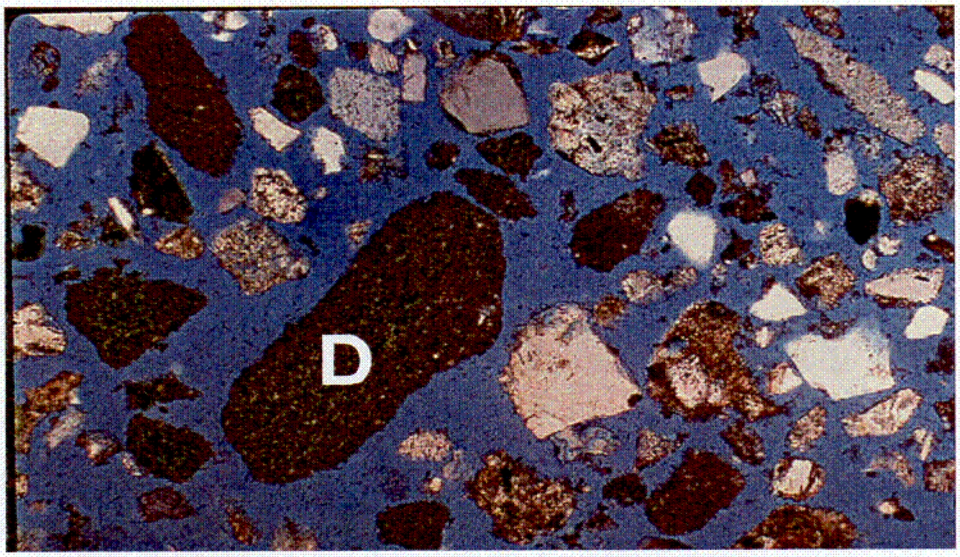

Figure 4-14. Photomicrograph of well cuttings of alluvium from borehole NC–EWDP–02D taken at a depth of 1,165 to 1,170 ft. The dark fragments (D) in this photo are composed of microcrystalline dolomite. Figure is 2.6 mm across.

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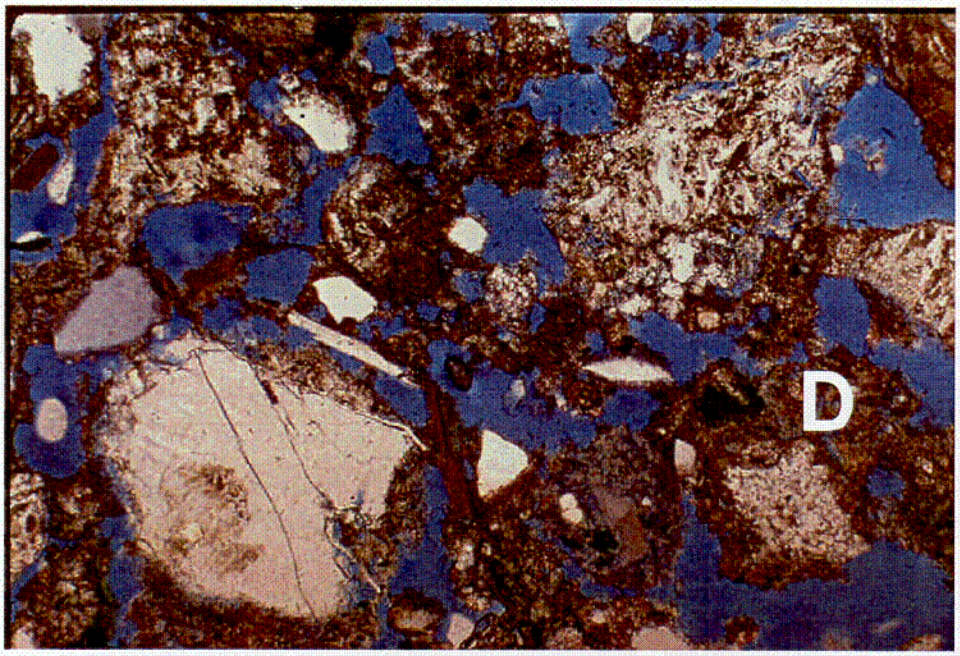

Figure 4-15. Photomicrograph of microcrystalline dolomite (D) cementing components of the alluvium in borehole NC–EWDP–02D at a depth of 1,125 to 1,130 ft. The dolomite cement is likely a replacement of the original alluvial cement which consisted of silt-sized feldspar particles. Figure is 2.6 mm across.

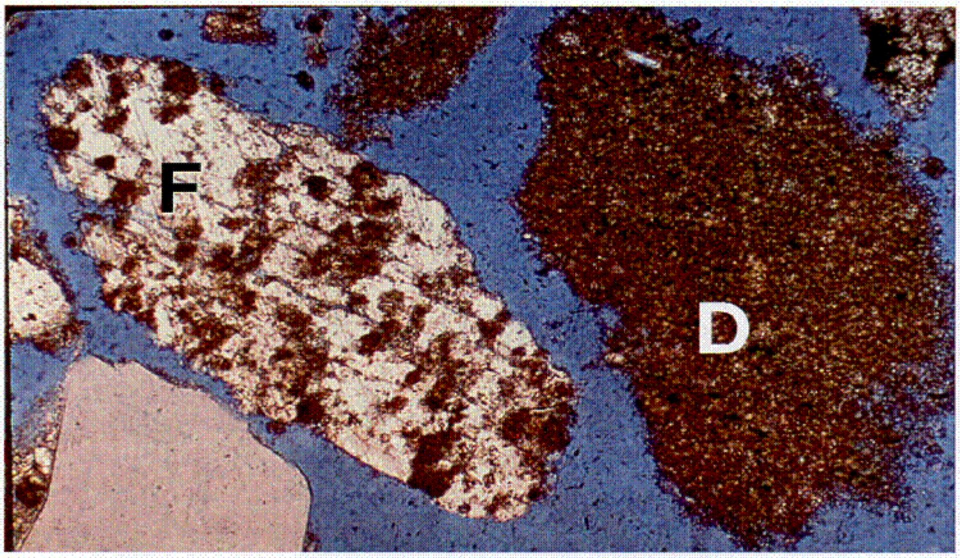

Figure 4-16. Photomicrograph of a dolomite fragment (D) and a feldspar crystal (F) taken from borehole NC–EWDP–02D at a depth of 1,165 to 1,170 ft. The feldspar fragment is partially replaced by microcrystalline dolomite which indicates that dolomite in the alluvium is a replacement after feldspar. Figure is 1.0 mm across.

C10

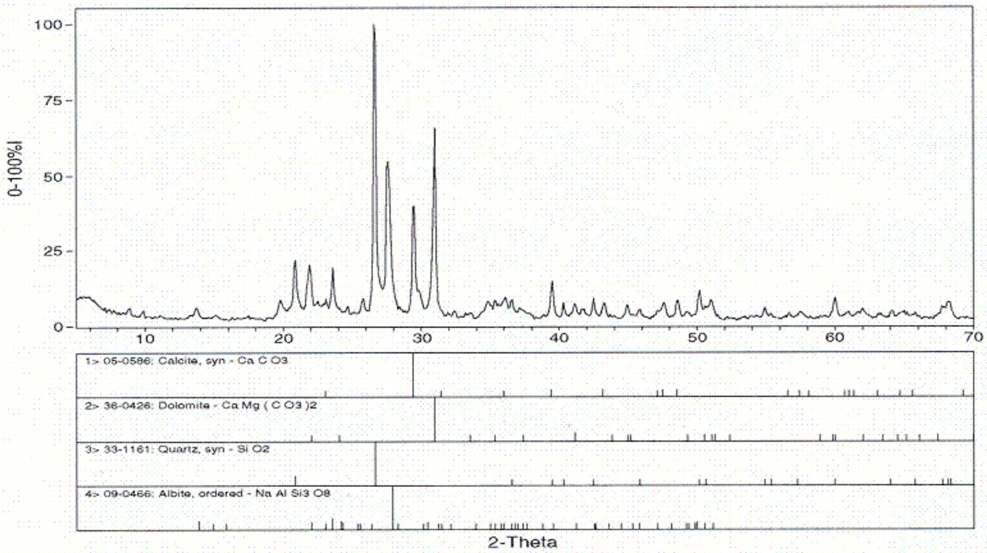

Figure 4-17. X-ray diffraction pattern of well cuttings of alluvium taken from borehole NC–EWDP–02D at a depth of 1,445 to 1,450 ft. Components of the alluvium include calcite, dolomite, quartz, and albite.

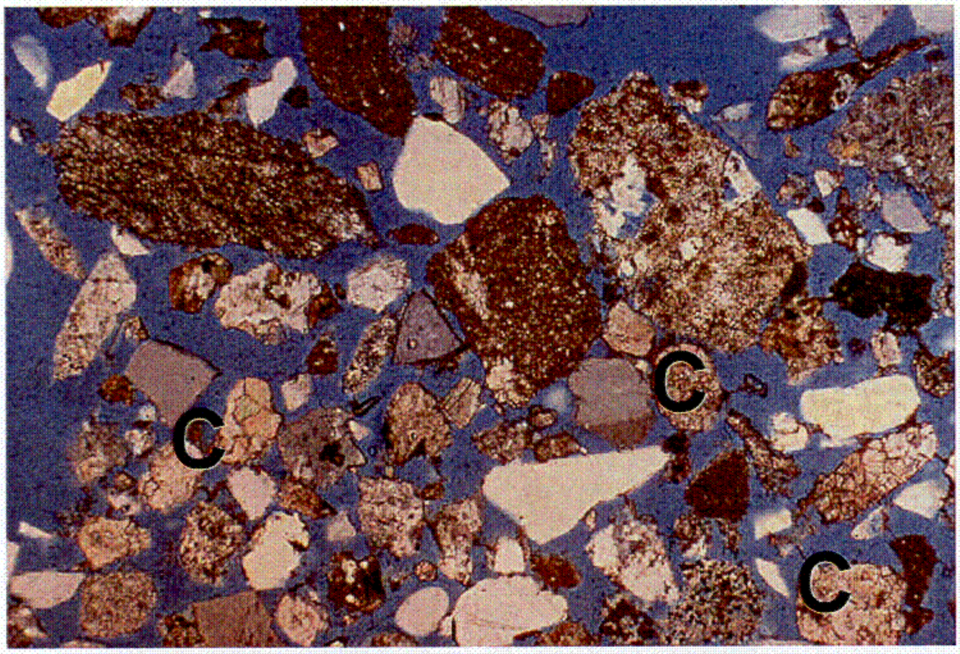

Figure 4-18. Photomicrograph of well cuttings of alluvium from borehole NC–EWDP–02D taken at a depth of 1,445 to 1,450 ft. The well cuttings contain numerous calcite fragments (C) composed of interlocking, equigranular calcite crystals. Figure is 2.6 mm across.

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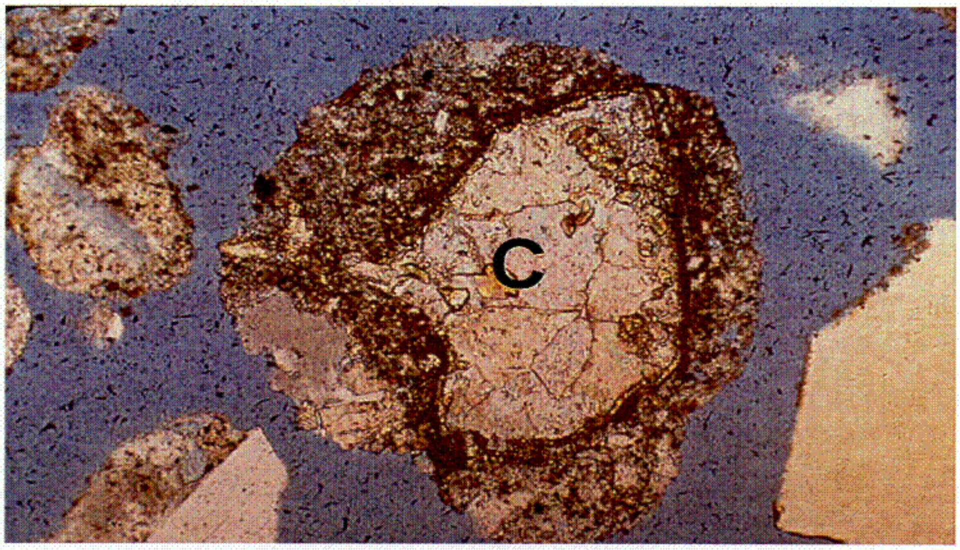

Figure 4-19. Photomicrograph of sparry calcite (C) replacing a feldspar phenocryst in a volcanic rock fragment. This sample was taken from well cuttings from borehole NC–EWDP–02D at a depth of 1,195 to 1,200 ft. Figure is 1.0 mm across.

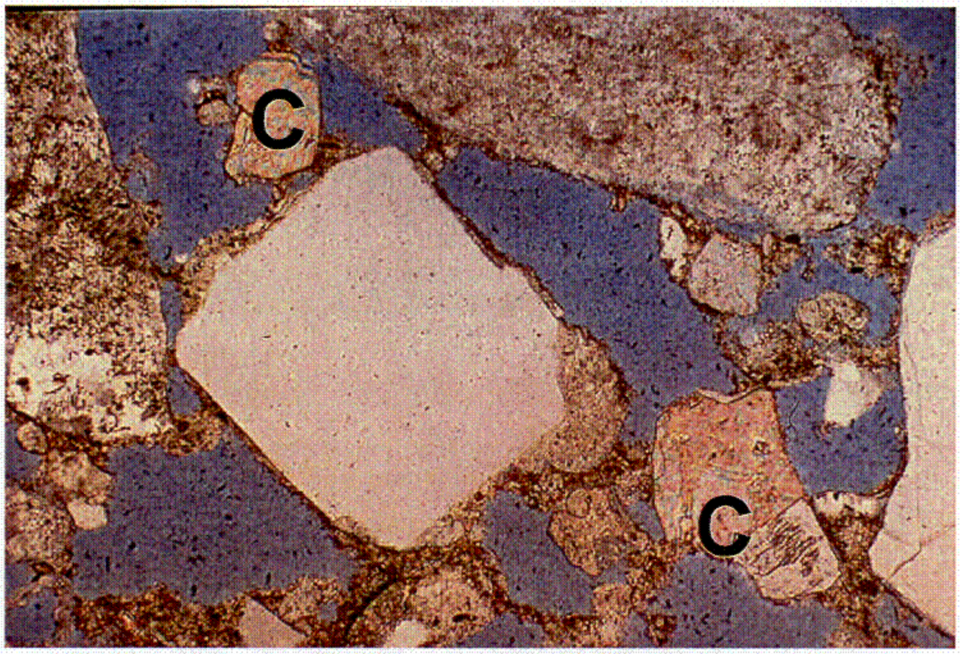

Figure 4-20. Photomicrograph of calcite (C) which has replaced feldspar components of the alluvium. The calcite fragment at the bottom right of the photo was originally a twinned feldspar crystal. Twinning in feldspar crystals is sometimes preserved in the replacement calcite. This sample is from well cuttings from borehole NC–EWDP–02D taken at a depth of 1,385 to 1,390 ft. Also, note the microcrystalline dolomite that rims the components of the alluvium. Figure is 1.0 mm across.

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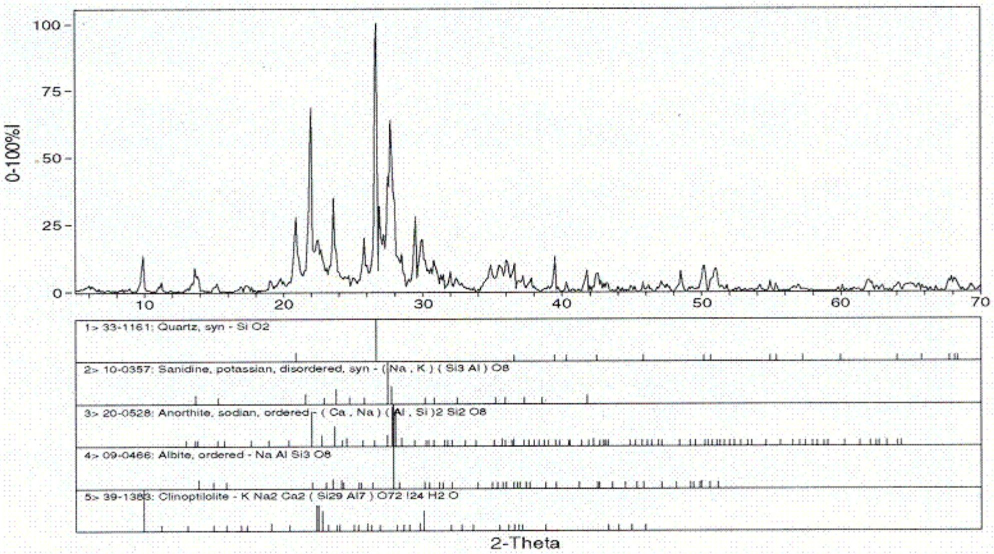

Figure 4-21. X-ray diffraction pattern of well cuttings of alluvium taken from borehole NC–EWDP–02D at a depth of 935 to 940 ft. Mineralogic components include quartz, feldspar, and clinoptilolite.

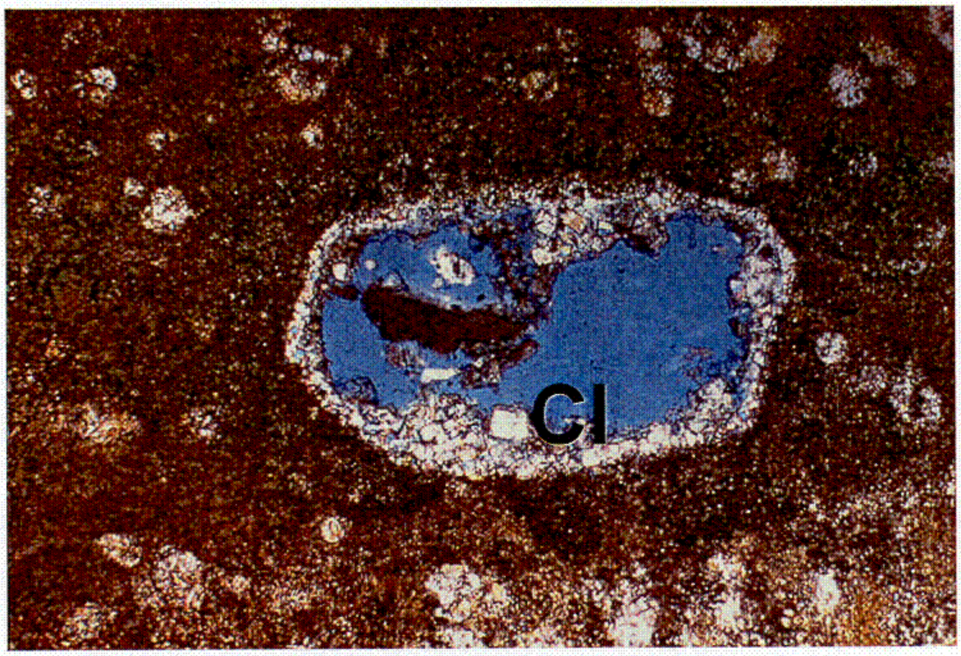

Figure 4-22. Photomicrograph of clinoptilolite (Cl) filling open space left by feldspar dissolution. Samples was taken from borehole NC–Washburn–1X at a depth of 375 to 380 ft. The crystals rimming the large open space left by dissolution of the large feldspar phenocryst have a distinctive blocky or tabular shape which is indicative of clinoptilolite. Figure is 1.0 mm across.

C13

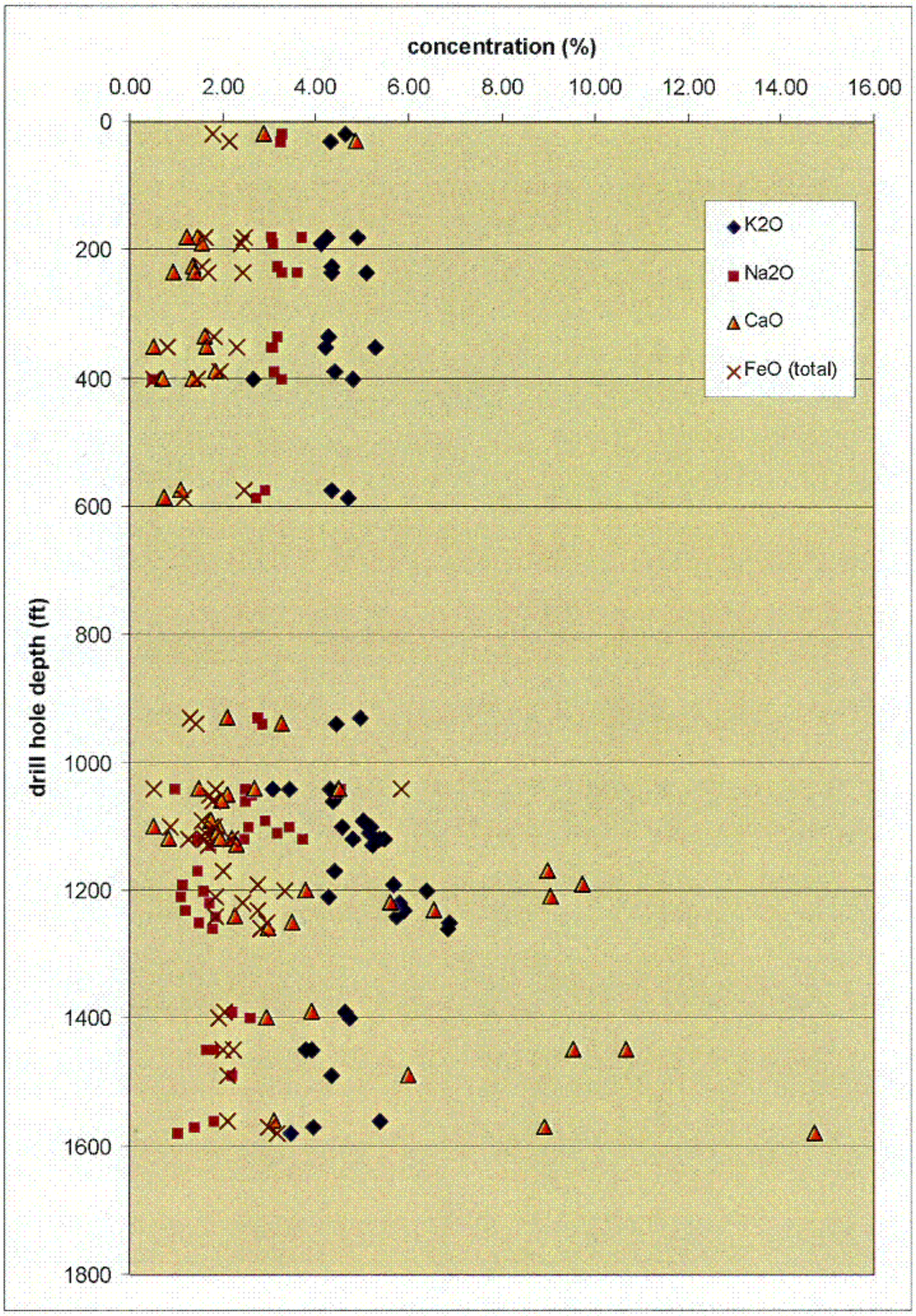

Figure 4-23. Results of x-ray fluorescence analyses for selected major cations from well NC–EWDP–02D cuttings.

C14

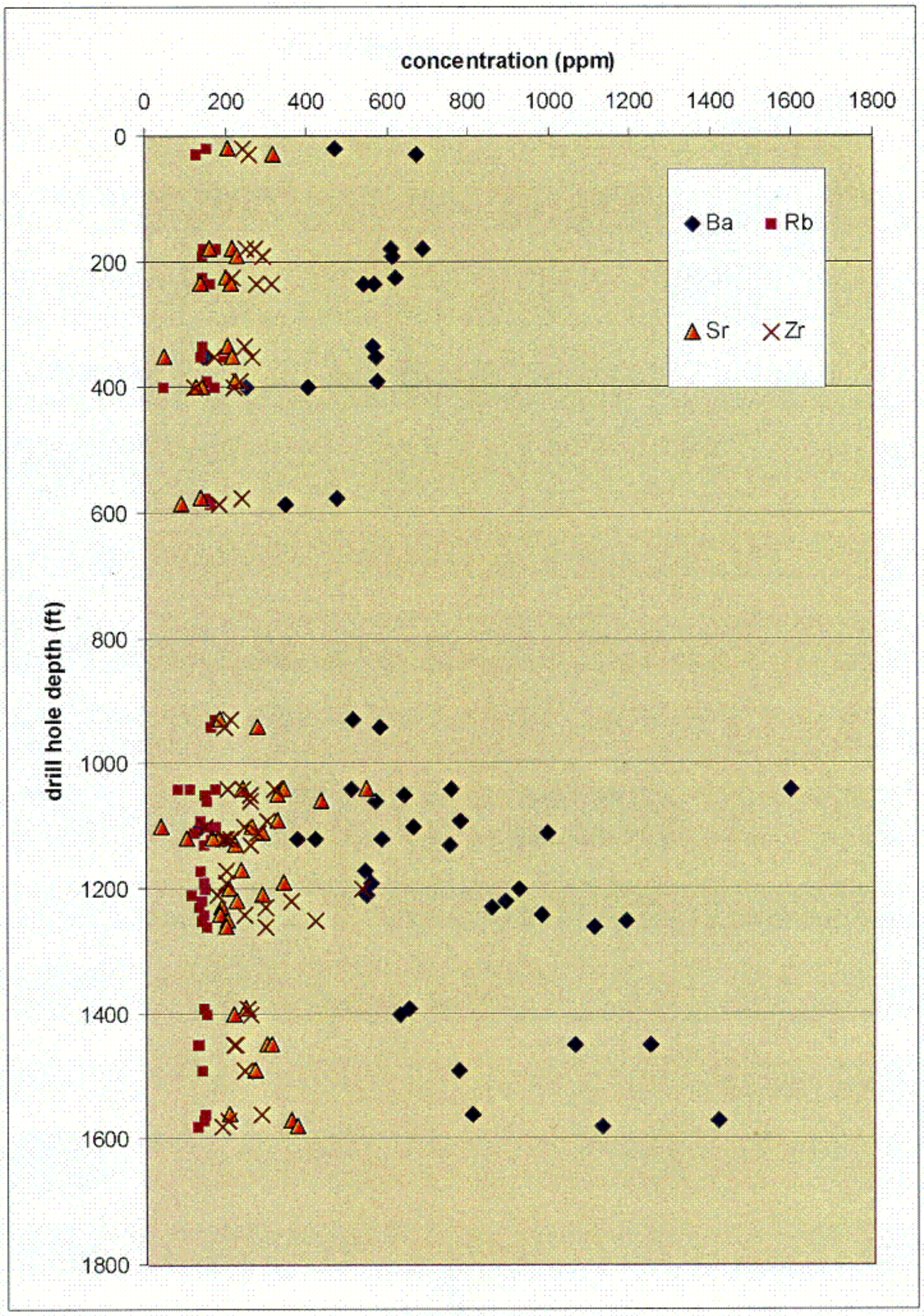

Figure 4-24. **Results of x-ray fluorescence analyses for selected trace elements from well NC–EWDP–02D cuttings.**

C15

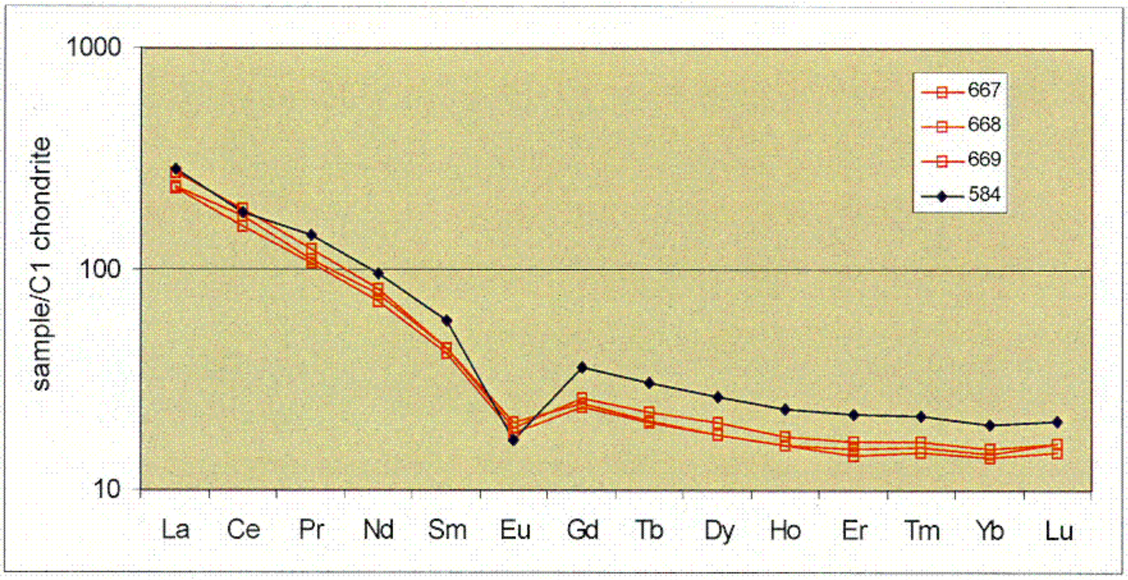

Figure 4-25. Results of inductively coupled plasma mass-spectrometry analyses for rare earth elements, normalized to C1 chondrites, for selected samples from well NC–EWDP–02D. Samples from the tertiary volcanic tuff (667, 668, and 669) exhibit differences in Eu and Ce anomalies relative to the alluvial sample (584).

C16

5 SUMMARY AND CONCLUSIONS

Characterization of the saturated alluvium in Fortymile Wash is an important and ongoing process. The current schedule for characterization of the proposed Yucca Mountain repository, coupled with statutory requirements for NRC review of a potential license application from DOE, make the timely availability of alluvium characterization data important for NRC staff. This report consolidates available geochemical data collected by several organizations from Nye County EWDP wells through October 2000. The data are presented in an organized electronic file format for ease of access by NRC staff. The report also presents geochemical and mineralogical results of CNWRA analyses of selected cutting samples from EWDP wells NC–EWDP–02D and NC–Washburn–1X. DOE characterization of the saturated alluvium within Fortymile Wash is far from complete. Data contained in this report will be an important resource for regulatory reviews and model development as NRC evaluation of the DOE Yucca Mountain characterization program proceeds. Moreover, the data contained in this report can be combined with other recent CNWRA studies of the alluvium within Fortymile Wash and adjacent areas (e.g., La Femina et al., 2000; Ressler et al., 2000) to provide an integrated view of this important component of the potential saturated zone transport pathway.

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APPENDIX A
DATA FILE CONTENT, FORMAT, AND LOCATION

Data Type	Source	Path	Filename(s)	Format(s)	Content
EWDP Water Chemistry					
	CNWRA	/Water/CNWRA	CNWRA_EWDP_Water.xls	MS Excel 97 Quattro Pro 8*	Water chemistry results for spot check sampling conducted in May and November 1999.
	DOE/USGS	/Water/DOE	DTN_GS010308312322_002.xls DTN_GS010308312322_003.xls	MS Excel 97 Quattro Pro 8	Results of USGS sampling of EWDP wells and wells from nearby areas through Dec 1999. File.003 contains qualified data, whereas file.002 contains data that have yet to be qualified by DOE. Data in these files supercede data previously submitted as DTN GS000308312322.003
	DOE/USGS	/Water/DOE	DTN_GS990808312322_001_002.xls	MS Excel 97 Quattro Pro 8	USGS chemistry and isotopic data from wells in the Amargosa Valley region. Combines DTNs 001 and 002.
	DOE/USGS	/Water/DOE	DTN_GS000308312322_003.xls	MS Excel 97 Quattro Pro 8	USGS data from EWDP sampling through December 1999. Data are superceded by DTNs as noted above. File is included here for reference only.
	DOE/LANL	/Water/DOE	DTN_LA9907AM831234_001.xls DTN_LA9907AM831234_002.xls	MS Excel 97 Quattro Pro 8	Results from EWDP sampling conducted by LANL personnel through June 1999.
	UNLV	/Water/UNLV	DTN_UN0010SPA008KS_001.xls DTN_UN0010SPA008KS_002.xls	MS Excel 97 Quattro Pro 8	Results of EWDP well sampling by UNLV during the May (001) and November (002) 1999 sampling events.
	Nye County	/Water/NyeCo	NC_General_Chem.xls NC_Isotopic_Data.xls NC_Radioactivity.xls	MS Excel 97 Quattro Pro 8	Results of analyses conducted by Nye County and its contractors for EWDP wells through October 2000.
Well Cuttings					

Data Type	Source	Path	Filename(s)	Format(s)	Content
	CNWRA	/Cuttings	Cuttings_ID.xls	MS Excel 97 Quattro Pro 8	Sample identification for all cuttings from NC-EWDP-02D and NC-Washburn-1X, including identification of samples processed for analyses. Also posted as hard copy in Appendix B.
	CNWRA	/Cuttings /CuttingsChem	Cuttings_XRF.xls	MS Excel 97 Quattro Pro 8	Results of XRF and LOI for selected samples.
	CNWRA	/Cuttings /CuttingsChem	Cuttings_ICPMS.xls	MS Excel 97 Quattro Pro 8	Results of ICP-MS analyses for selected samples.
	CNWRA	/Cuttings /XRD_Peaks	549.xls to 848.xls (69 files)	MS Excel 97	Peak analyses and intensities for analyzed samples. Also posted as hard copies in Appendix C.
	CNWRA	/Cuttings /XRD_Patterns	549.eps to 848.eps (69 files)	eps format readable in Adobe Illustrator	XRD patterns of analyzed samples. Also posted as hard copies in Appendix C.
	CNWRA	/Cuttings /XRD_Raw	x549.mdi to x878.mdi (72 files)	mdi format, readable as text	Raw XRD pattern files for each analyzed sample. Files include patterns for reference materials (e.g., quartz).
	CNWRA	/Cuttings /ThinSections	578_1_26.jpg to 869_18_26.jpg (90 files)	JPEG images	Files representing photomicrographs of thin sections of selected samples. Images are taken under polarized light. File number indicates sample number, picture sequence, and size of field of view (in mm).

* Quattro Pro file extensions (*.wb3) are not explicitly listed in the table.

Appendix A: Data file content, format, and location.

APPENDIX B
SUMMARY OF CUTTINGS FROM WELLS NC–EWDP–02D AND NC–WASHBURN–1X

NC-EWDP-02D	SMF ID	SampleID	Interval Depth (ft) Top	Interval Depth (ft) Bottom	XRF	ICP-MS	XRD	Thin Section
Container ID: 1002648								
	1010548	548	5.0	10.0				
	1010549	549	15.0	20.0	xrf	icpms	xrd	
	1010550	550	25.0	30.0	xrf	icpms	xrd	
	1010551	551	35.0	40.0				
	1010552	552	45.0	50.0				
	1010553	553	55.0	60.0				
	1010554	554	65.0	70.0				
	1010555	555	75.0	80.0				
	1010556	556	85.0	90.0				
	1010558	558	95.0	100.0				
	1010559	559	105.0	110.0				
	1010560	560	115.0	120.0				
	1010561	561	125.0	130.0				
	1010562	562	135.0	140.0				
	1010563	563	145.0	150.0				
	1010564	564	155.0	160.0				
	1010565	565	165.0	170.0				
	1010566	566	175.0	180.0	xrf	icpms	xrd	
		566A	175.0	180.0	xrf	icpms	xrd	
	1010567	567	185.0	190.0	xrf	icpms	xrd	
	1010568	568	195.0	200.0				
	1010569	569	210.0	215.0				
	1010570	570	220.0	225.0	xrf	icpms	xrd	
	1010571	571	230.0	235.0	xrf	icpms	xrd	
		571A	230.0	235.0	xrf	icpms	xrd	
	1010572	572	240.0	245.0				
	1010573	573	255.0	260.0				
	1010574	574	270.0	275.0				
	1010575	575	280.0	285.0				
	1010576	576	290.0	295.0				
	1010577	577	300.0	305.0				
	1010578	578	330.0	335.0	xrf		xrd	TS
	1010579	579	345.0	350.0	xrf	icpms	xrd	
		579A	345.0	350.0	xrf		xrd	

NC-EWDP-02D	SMF ID	SampleID	Interval Depth (ft) Top	Interval Depth (ft) Bottom	XRF	ICP-MS	XRD	Thin Section
	1010580	580	355.0	360.0				
	1010581	581	365.0	370.0				
	1010582	582	375.0	380.0				
	1010583	583	385.0	390.0	xrf	icpms	xrd	
	1010584	584	395.0	400.0	xrf	icpms	xrd	TS
		584A	395.0	400.0	xrf		xrd	
	1010585	585	405.0	410.0				
	1010586	586	415.0	420.0				
	1010587	587	430.0	435.0				
	1010589	589	450.0	455.0				
	1010590	590	460.0	465.0				
	1010591	591	470.0	475.0				
	1010592	592	480.0	485.0				
	1010593	593	490.0	495.0				
Container ID 01002649								
	1010595	595	500.0	505.0				
	1010596	596	510.0	515.0				
	1010597	597	520.0	525.0				
	1010598	598	530.0	535.0				
	1010599	599	540.0	545.0				
	1010600	600	550.0	555.0				
	1010601	601	560.0	565.0				
	1010602	602	570.0	575.0	xrf	icpms	xrd	
	1010603	603	580.0	585.0	xrf	icpms	xrd	
	1010604	604	590.0	595.0				
	1010605	605	600.0	605.0				
	1010606	606	610.0	615.0				
	1010607	607	620.0	625.0				
	1010608	608	630.0	635.0				
	1010609	609	640.0	645.0				
	1010610	610	650.0	655.0				
	1010611	611	660.0	665.0				
	1010612	612	670.0	675.0				
	1010613	613	680.0	685.0				
	1010614	614	690.0	695.0				

NC-EWDP-02D	SMF ID	SampleID	Interval Depth (ft) Top	Interval Depth (ft) Bottom	XRF	ICP-MS	XRD	Thin Section
	1010615	615	700.0	705.0				
	1010616	616	710.0	715.0				
	1010617	617	720.0	725.0				
	1010618	618	730.0	735.0				
	1010619	619	740.0	745.0				
	1010620	620	750.0	755.0				
	1010621	621	760.0	765.0				
	1010622	622	770.0	775.0				
	1010623	623	780.0	785.0				
	1010624	624	795.0	800.0				
	1010625	625	805.0	810.0				
	1010626	626	815.0	820.0				
	1010627	627	825.0	830.0				
	1010628	628	835.0	840.0				
	1010629	629	845.0	850.0				
	1010630	630	855.0	860.0				
	1010631	631	865.0	870.0				
	1010632	632	875.0	880.0				
	1010633	633	885.0	890.0				
	1010634	634	895.0	900.0				
	1010635	635	905.0	910.0				
	1010636	636	915.0	920.0				
	1010637	637	925.0	930.0	xrf	icpms	xrd	
	1010638	638	935.0	940.0	xrf		xrd	
	1010639	639	945.0	950.0				
	1010640	640	955.0	960.0				
	1010641	641	965.0	970.0				
	1010642	642	975.0	980.0				
	1010643	643	985.0	990.0				
	1010644	644	995.0	1000.0				
Container ID: 01002650								
	1010645	645	1005.0	1010.0				
	1010646	646	1015.0	1020.0				
	1010647	647	1025.0	1030.0				
	1010648	648	1035.0	1040.0	xrf	icpms	xrd	

NC-EWDP-02D	SMF ID	SampleID	Interval Depth (ft) Top	Interval Depth (ft) Bottom	XRF	ICP-MS	XRD	Thin Section
		648A	1035.0	1040.0	xrf		xrd	
		648B	1035.0	1040.0	xrf	icpms	xrd	
	1010649	649	1045.0	1050.0	xrf	icpms	xrd	TS
	1010650	650	1055.0	1060.0	xrf	icpms	xrd	TS
	1010651	651	1065.0	1070.0				
	1010652	652	1075.0	1080.0				
	1010653	653	1085.0	1090.0	xrf	icpms	xrd	
	1010654	654	1095.0	1100.0	xrf	icpms	xrd	
		654A	1095.0	1100.0	xrf		xrd	TS
	1010655	655	1105.0	1110.0	xrf	icpms	xrd	
	1010656	656	1115.0	1120.0	xrf	icpms	xrd	
		656A	1115.0	1120.0	xrf		xrd	TS
		656B	1115.0	1120.0	xrf		xrd	TS
	1010657	657	1125.0	1130.0	xrf	icpms	xrd	TS
	1010658	658	1135.0	1140.0				
	1010659	659	1145.0	1150.0				
	1010660	660	1155.0	1160.0				
	1010661	661	1165.0	1170.0	xrf	icpms	xrd	TS
	1010662	662	1175.0	1180.0				
	1010663	663	1185.0	1190.0	xrf	icpms	xrd	
	1010664	664	1195.0	1200.0	xrf	icpms	xrd	TS
	1010665	665	1205.0	1210.0	xrf	icpms	xrd	TS
	1010666	666	1215.0	1220.0	xrf	icpms	xrd	TS
	1010667	667	1225.0	1230.0	xrf	icpms	xrd	
	1010668	668	1235.0	1240.0	xrf	icpms	xrd	
	1010669	669	1245.0	1250.0	xrf	icpms	xrd	
	1010670	670	1255.0	1260.0	xrf	icpms	xrd	
	1010671	671	1265.0	1270.0				
	1010672	672	1275.0	1280.0				
	1010673	673	1285.0	1290.0				
	1010674	674	1295.0	1300.0				
	1010675	675	1305.0	1310.0				
	1010676	676	1315.0	1320.0				
	1010678	678	1325.0	1330.0				
	1010679	679	1335.0	1340.0				
	1010680	680	1345.0	1350.0				

NC-EWDP-02D	SMF ID	SampleID	Interval Depth (ft) Top	Interval Depth (ft) Bottom	XRF	ICP-MS	XRD	Thin Section
	1010681	681	1355.0	1360.0				
	1010682	682	1365.0	1370.0				
	1010683	683	1375.0	1380.0				
	1010684	684	1385.0	1390.0	xrf	icpms	xrd	TS
	1010685	685	1395.0	1400.0	xrf	icpms	xrd	
	1010686	686	1405.0	1410.0				
	1010687	687	1415.0	1420.0				
	1010688	688	1425.0	1430.0				
	1010689	689	1435.0	1440.0				
	1010690	690	1445.0	1450.0	xrf	icpms	xrd	TS
		690A	1445.0	1450.0	xrf	icpms	xrd	
		690B	1445.0	1450.0				TS
	1010691	691	1455.0	1460.0				
	1010692	692	1465.0	1470.0				
	1010693	693	1475.0	1480.0				
	1010694	694	1485.0	1490.0	xrf	icpms	xrd	
	1010695	695	1495.0	1500.0				
	1010696	696	1505.0	1510.0				
	1010697	697	1515.0	1520.0				
	1010698	698	1525.0	1530.0				
	1010699	699	1535.0	1540.0				
	1010700	700	1545.0	1550.0				
	1010701	701	1555.0	1560.0	xrf	icpms	xrd	TS
	1010702	702	1565.0	1570.0	xrf	icpms	xrd	
	1010703	703	1575.0	1580.0	xrf	icpms	xrd	
	1010704	704	1585.0	1590.0				
	1010705	705	1595.0	1600.0				
	1010706	706	1605.0	1610.0				
	1010707	707	1615.0	1620.0				

NC-Washburn-1X Container ID: 01002655	SMF ID	Sample ID	Interval Depth (ft) Top	Interval Depth (ft) Bottom	XRF	ICP-MS	XRD	Thin Section
	1010819	**819**	5.0	10.0				
	1010820	**820**	15.0	20.0				
	1010821	**821**	25.0	30.0				
	1010822	**822**	35.0	40.0				
	1010823	**823**	45.0	50.0				
	1010824	**824**	55.0	60.0				
	1010825	**825**	65.0	70.0				
	1010826	**826**	75.0	80.0				
	1010827	**827**	85.0	90.0				
	1010828	**828**	95.0	100.0				
	1010829	**829**	105.0	110.0				
	1010830	**830**	115.0	120.0				
	1010831	**831**	125.0	130.0				
	1010832	**832**	135.0	140.0				
	1010833	**833**	145.0	150.0				
	1010834	**834**	155.0	160.0				
	1010835	**835**	165.0	170.0				
	1010836	**836**	175.0	180.0				
	1010837	**837**	185.0	190.0				
	1010838	**838**	195.0	200.0				
	1010839	**839**	205.0	210.0				
	1010840	**840**	215.0	220.0				
	1010841	**841**	225.0	230.0	xrf	icpms	xrd	
		841A	225.0	230.0	xrf	icpms	xrd	
	1010842	**842**	235.0	240.0	xrf	icpms	xrd	
	1010843	**843**	245.0	250.0				
	1010844	**844**	255.0	260.0				
	1010845	**845**	265.0	270.0				
	1010846	**846**	275.0	280.0				
	1010847	**847**	285.0	290.0				
	1010848	**848**	295.0	300.0				
	1010849	**849**	305.0	310.0				
	1010850	**850**	315.0	320.0				
	1010851	**851**	325.0	330.0				
	1010852	**852**	335.0	340.0	xrf	icpms	xrd	
	1010853	**853**	345.0	350.0	xrf	icpms	xrd	
	1010854	**854**	355.0	360.0	xrf	icpms	xrd	
	1010855	**855**	365.0	370.0	xrf	icpms	xrd	TS
	1010856	**856**	375.0	380.0	xrf	icpms	xrd	TS

NC-Washburn-1X Container ID: 01002655	SMF ID	Sample ID	Interval Depth (ft) Top	Interval Depth (ft) Bottom	XRF	ICP-MS	XRD	Thin Section
	1010857	**857**	385.0	390.0				
	1010858	**858**	395.0	400.0				
	1010859	**859**	410.0	415.0				
	1010860	**860**	420.0	425.0				
	1010861	**861**	455.0	460.0				
	1010862	**862**	465.0	470.0				
	1010863	**863**	475.0	480.0				
	1010864	**864**	485.0	490.0	xrf	icpms	xrd	TS
	1010865	**865**	495.0	500.0	xrf	icpms	xrd	
	1010866	**866**	505.0	510.0	xrf	icpms	xrd	
	1010867	**867**	515.0	520.0	xrf	icpms	xrd	TS
	1010868	**868**	525.0	530.0	xrf	icpms	xrd	TS
	1010869	**869**	535.0	540.0	xrf	icpms	xrd	TS
	1010870	**870**	545.0	550.0	xrf	icpms	xrd	
	1010871	**871**	555.0	560.0	xrf	icpms	xrd	
	1010872	**872**	570.0	575.0	xrf	icpms	xrd	
	1010873	**873**	580.0	585.0	xrf	icpms	xrd	
	1010874	**874**	590.0	595.0				
	1010875	**875**	600.0	605.0				
	1010876	**876**	610.0	615.0	xrf	icpms	xrd	
	1010877	**877**	620.0	625.0	xrf	icpms	xrd	
	1010878	**878**	630.0	635.0	xrf	icpms	xrd	
	1010879	**879**	640.0	645.0				
	1010880	**880**	650.0	655.0				