DESCRIPTION AND HYDROGEOLOGIC IMPLICATIONS OF CORED SEDIMENTARY MATERIAL FROM THE 1975 DRILLING PROGRAM AT THE RADIOACTIVE WASTE MANAGEMENT COMPLEX, IDAHO

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FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC UNITS

The following factors can be used to convert inch-pound units published herein to the International System (SI) of metric units.

Multiply inch-pound units	By	To obtain metric units
inches (in)	2.54	centimeters (cm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)

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ABSTRACT

Samples of sedimentary material from interbeds between basalt flows and from fractures in the flows, taken from two drill cores at the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory were analyzed for 1) particle-size distribution, 2) bulk mineralogy, 3) clay mineralogy, 4) cation-exchange capacity, and 5) carbonate content. Thin sections of selected sedimentary material were made for petrographic examination. These analyses are needed for a characterization of paths and rates of movement of radionuclides transported by infiltrating water.

Preliminary interpretations indicate that 1) it may be possible to distinguish the various sedimentary interbeds on the basis of their mineralogy, 2) the presence of carbonate horizons in sedimentary interbeds may be utilized to approximate the time of exposure and the climate while the surface was exposed, and 3) the type and orientation of fracture-filling material may be utilized to determine the mechanism by which fractures were filled.

INTRODUCTION

The Idaho National Engineering Laboratory (INEL) is located on the Snake River Plain in southeastern Idaho (fig. 1). Basalt flows underlying the Plain form a fractured-rock aquifer. Their hydrogeologic character has been fundamentally affected, however, by the fact that sediments are interbedded with many of the flows and fill many of the fractures; therefore, infiltration and flow through the near-surface rock involve both fractured and porous media.

At the Radioactive Waste Management Complex (RWMC), at the INEL, the presence of interbeds and fracture fillings may have a significant effect on downward movement of radionuclides from the surface or the near-surface zone, partly because of the transmissive character of the sediment and partly because of the possibility of adsorption of solutes on mineral grains. The presence or absence of sediments in the basalt section at a given locality, and their thickness, and physical, and mineralogical character, may therefore prove important in understanding how any radionuclides released near the land surface are likely to move downward through the soil and near-surface rock.

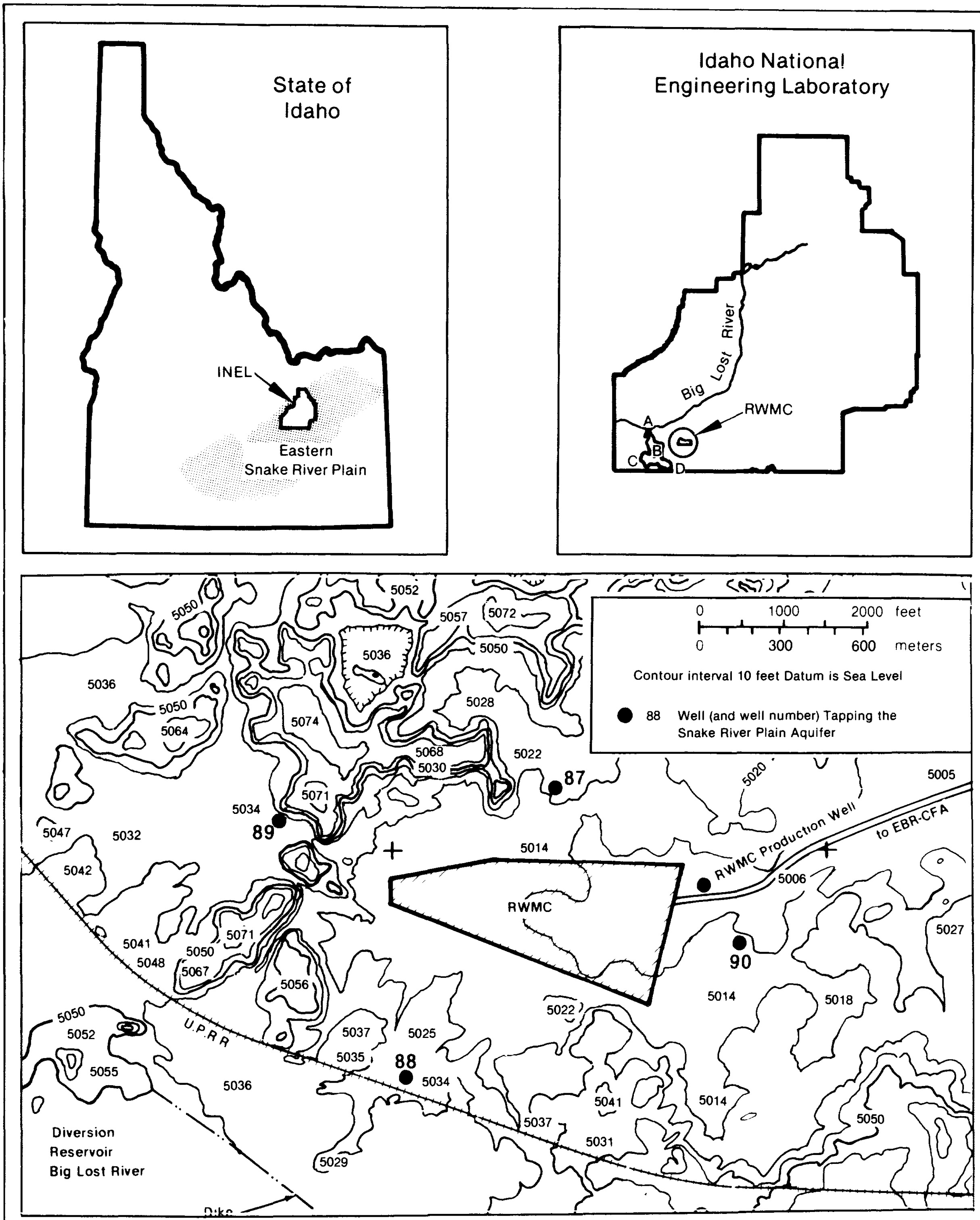

Figure 1.--Map of Idaho showing the location of the Idaho National Engineering Laboratory and a topographic map of the Radioactive Waste Management Complex area and a portion of the Big Lost River diversion area.

OBJECTIVE OF STUDY

The objective of this report is to describe the sedimentary interbeds and fracture fillings on the basis of their sedimentologic and stratigraphic character, mineralogy, and geochemistry, as background for a characterization of paths and rates of movement of radionuclides transported by infiltrating water.

LOCATION AND BACKGROUND OF STUDY AREA

The Radioactive Waste Management Complex (RWMC), a facility for the storage of low-level solid radioactive wastes, is in the southwest corner of the Idaho National Engineering Laboratory, a 2,320-km^2 nuclear-engineering installation in southeastern Idaho. The RWMC is approximately 87 km west of Idaho Falls, Idaho and 35 km southeast of Arco, Idaho at an altitude of about 1,500 m. The area is semi-arid, with annual precipitation ranging from 130 to 360 mm and averaging 200 mm.

The RWMC is in a shallow depression floored by basaltic lava flows and by wind- and water-deposited sediment. It is surrounded by uneven basalt flows of low relief (fig. 1).

Radioactive waste has been buried at the RWMC since 1952. Since 1970, only radioactive wastes with short half-lives have been buried. Transuranic wastes of long half life have been stored above ground on asphalt pads in retrievable containers.

PREVIOUS WORK AT THE RWMC

Drilling and sample handling techniques used in collecting the core samples discussed in this report were described in an earlier report (Burgus and Maestas, 1976). Radiochemical analysis of the samples collected during this study detected no waste radionuclides in fifteen sediment samples collected from these cores. However, an earlier four-year study completed in 1974, suggested that radionuclides had migrated from the RWMC downward to two sedimentary interbeds (Barraclough and others, 1976).

GEOLOGY

SNAKE RIVER PLAIN

The Snake River Plain is a depression filled with basalt, rhyolite, and terrestrial sediments that extends in a 500-km arc across southern Idaho from the Yellowstone Plateau on the east to the Oregon border on the west. The geology of the INEL area was discussed by Robertson and others (1974).

SEDIMENTARY BEDS WITHIN THE SNAKE RIVER BASALT FLOWS

Terrestrial sedimentary beds occur between many basalt flows in the Snake River Plain and represent extended periods of eruptive-volcanic quiescence. These sedimentary beds are generally discontinuous and their thicknesses are highly variable reaching maximums of several tens of meters. Moreover, because both alluvial and eolian deposition of sediment occurred, the particle size may vary significantly through an interbedded unit.

Major sediment beds occur at or near the land surface and at depths of approximately 9 m, 34 m, and 73 m beneath the RWMC. The thickness of the surface sediment ranges from less than 1 m to about 8 m. Sediments "pinch out" laterally and basalt crops out on the north, south, and west flanks of the topographic depression. Much of the sediment is loess which is cemented by calcium carbonate, and some alluvial gravels are present.

The 9-m sedimentary interbed was not observed during an earlier study (Barraclough and others 1976). The top of the 34-m sedimentary interbed is reported at altitudes ranging from 1,494 m above mean sea level in well 90 (fig. 1) to 1,501 m in well 89, a difference of 7 m. The range in reported thickness is from 0.3 m in well 87 to 7.9 m in well 96.

The top of the 73-m sedimentary interbed is reported at altitudes ranging from 1,451 m in well 90 to 1,462 m in well 89. The range in thickness is from 1.2 m in wells 90 and 91 to 9.8 m in well 88.

Particle-size analyses and other geologic data for 8 surficial-sedimentary samples, 12 sedimentary samples from the 34-m interbed, 24 sedimentary samples from the 73-m interbed, and 2 samples from deeper layers were reported in Barraclough and others (1976).

METHODS

1975 CORE DRILLING PROGRAM

Drilling Techniques

Care was taken to minimize the possibility of radionuclide contamination of the core material during drilling or subsequent handling and storage of cores. The drilling techniques were discussed at length by Burgus and Maestas (1976). With the exception of interbed samples contained in plastic tubes, the samples were allowed to dry during the year which elapsed between collection and sample analysis. Therefore, desiccation may have altered the mineralogy of the samples.

Well Locations

Two core holes were originally planned for the 1975 drilling program, but a third hole was added due to coring difficulties encountered in well 96A. The three wells drilled, designated 93A, 96A, and 96B, are shown on figure 2. As 93A and 96B were the only wells completed below the 73-m sediment interbed, they were specifically examined and sampled. For generalized lithologic and geophysical logs of core-holes 93A and 96B, respectively, see figures 3 and 4.

Subsurface Relationships

The sedimentary relationships for the three wells are given in Table 1. Approximately 4.6 m of surface sediment occurs at each of the three wells. Burgus and Maestas (1976) reported that no samples of surficial sediment were collected from any of the three wells, but that the sedimentary material generally consisted of "mixed sediments, primarily tightly compacted clay," to a depth of 4.3 m in well 93A; "mixed sediments, some gravel but primarily hard clay," to a depth of 4.5 m in well 96A; and "mixed clay, sand, and gravel," to a depth of 4.8 m in well 96B. The 9-m sediment interbed was absent in well 93A but present in wells 96A and 96B at a depth of about 10.4 m. The thickness of this interbed is 0.4 and 1.7 m in the two holes. The 34-m interbed occurs at 29.7 m in well 93A and at 30.5 m in well 96B, and is 3.5-m thick in well 93A and 8.3-m thick in well 96B. The top of the 73-m interbed occurs at approximately 67 m in each well. The bottom of the interbed was not penetrated in either well. The interbed is at least 3.3-m thick in well 93A and at least 2.7-m thick in well 96B.

Table 1.--Sediment depth and thickness relationships (in meters)

	Well 93A	Well 96A	Well 96B
Bottom surficial sediment	4.3	4.5	4.8
Thickness surficial sediment	4.3	4.5	4.8
Top 9-m bed	--	10.5	10.6
Bottom 9-m bed	--	10.9	12.3
Thickness 9-m bed	0	0.4	1.7
Top 34-m bed	29.8	29.7[1]	30.5
Bottom 34-m bed	33.3	36.7[1]	38.8
Thickness 34-m Bed	3.5	6.9[2]	8.3
Top 73-m bed	67.9	Not reached	67.4
Bottom 73-m bed	71.1[1]	--	70.1[3]
Thickness 73-m bed	≥ 3.3[2]	--	>2.7[2]

[1] Depth approximate.
[2] Thickness approximate.
[3] Bottom of interbed at depth greater than depth indicated.

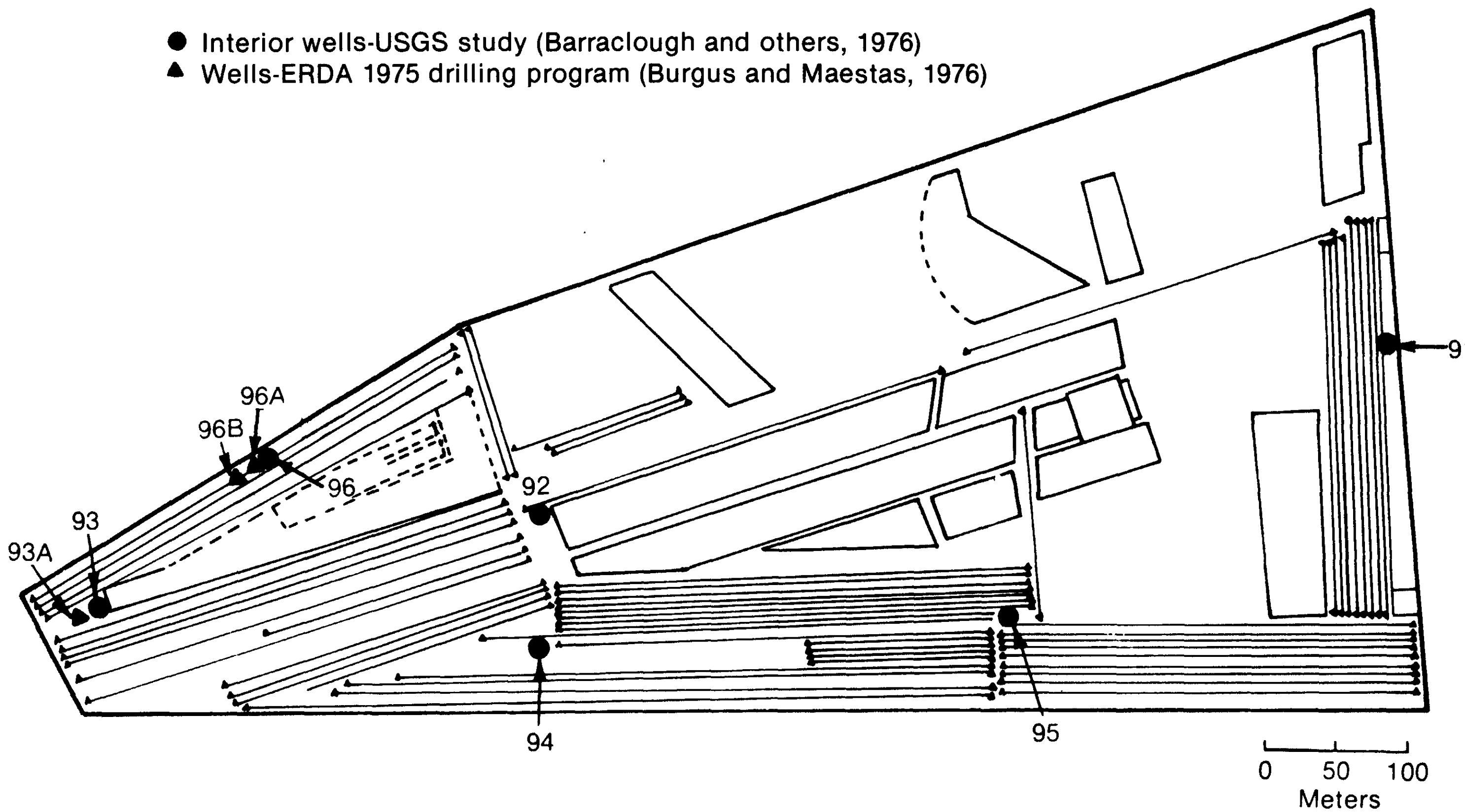

Figure 2.--Map of the Radioactive Waste Management Complex showing the location of drilled wells with respect to waste burial pits and trenches.

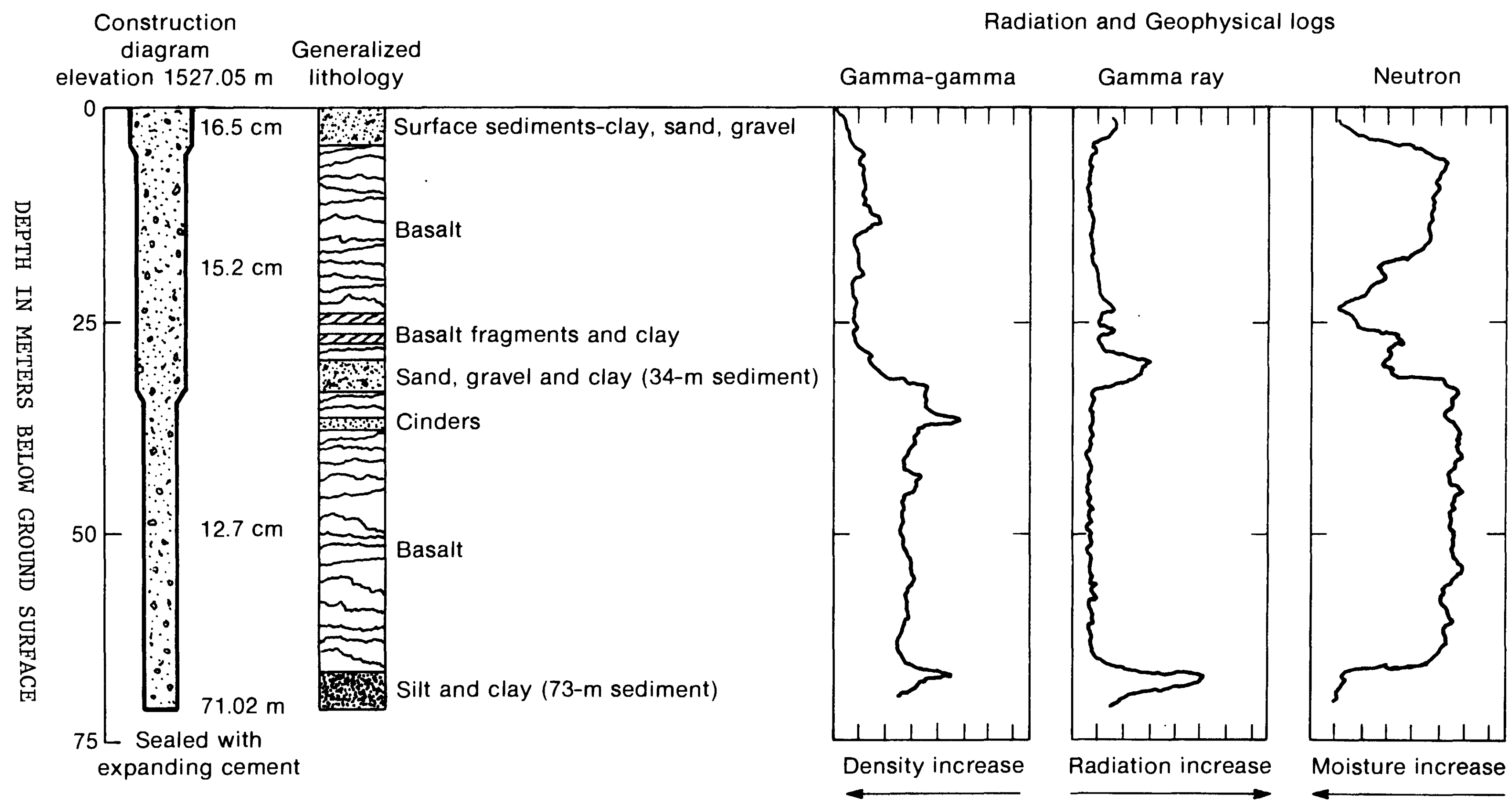

Figure 3.--Lithologic and geophysical logs - well 93A.

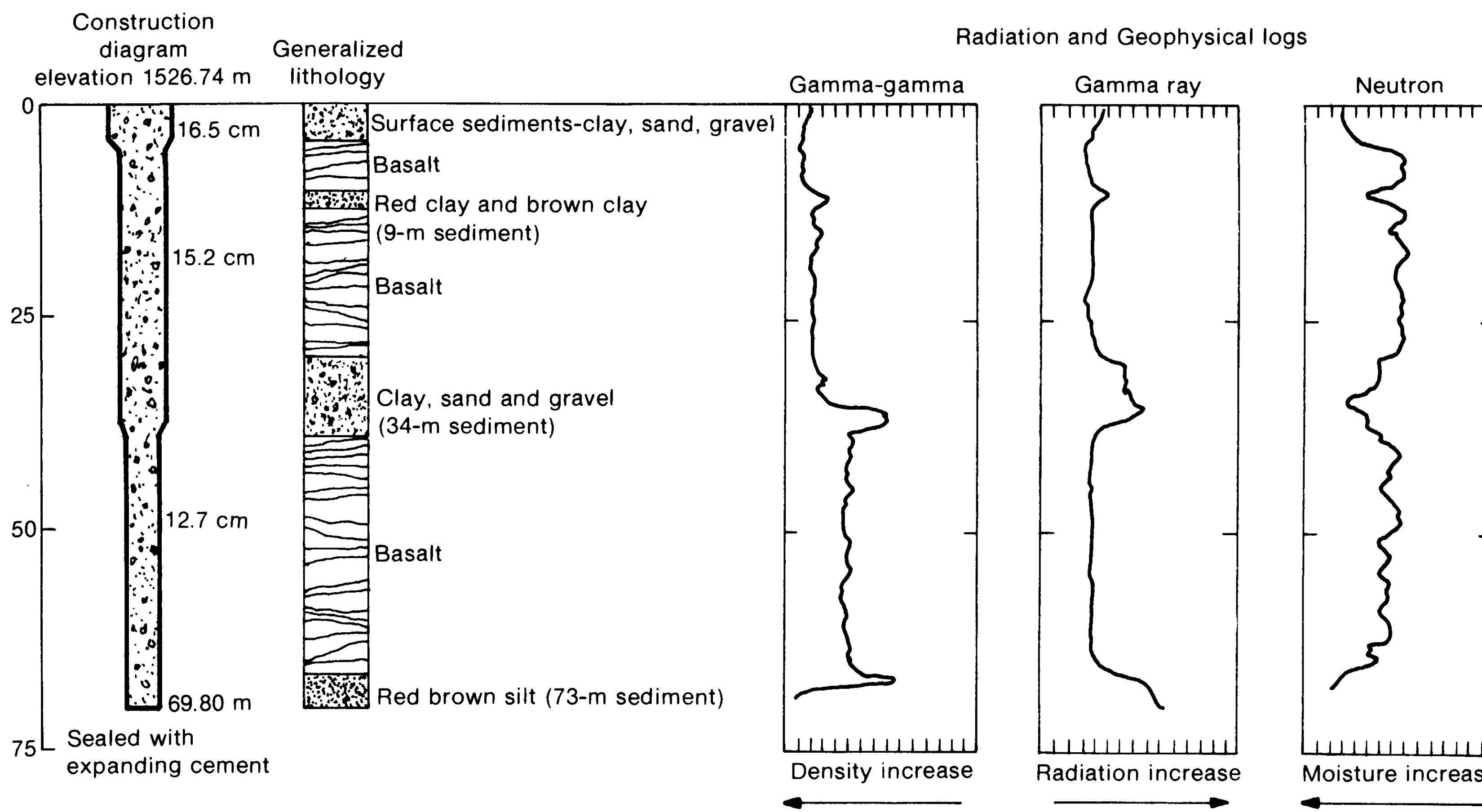

Figure 4.--Lithologic and geophysical logs - well 96B.

SAMPLING AND ANALYTICAL PROCEDURES

Sampling Procedures

Samples of sediment were taken from the cores from wells 93A and 96B at selected points where sufficient cored material was available. Cores from sediment interbeds were sampled at the top and bottom of the interbed and at points distributed throughout the unit. These samples were taken from the centers of the cores where the material had been relatively less disturbed by drilling. Additional sediment samples were scraped from basalt fracture infillings.

Analytical Procedures

The following analyses were made when sample size permitted, by the U.S. Geological Survey, Water Resources Division, Hydrologic Laboratory, Lakewood, Colorado:

1) particle-size distribution,
2) bulk mineralogy by x-ray diffraction,
3) clay mineralogy by x-ray diffraction,
4) cation-exchange capacity (CEC), and
5) carbonate content.

A further analysis, thin section optical petrography, was made at the INEL.

The procedures utilized for analyses 1 through 4 were discussed in Barraclough and others (1976), Appendix A-2. Analysis of carbonate content involved reacting a known weight of sediment with dilute hydrochloric acid; then; either measuring the carbon dioxide (CO_2) gas evolved or drying and reweighing the residue to determine the amount of carbonate lost as CO_2. The optical petrographic analyses were done by microscopic examination of thin sections of sediment and rock at the sediment-basalt interface.

Samples Analyzed

Table 2 contains descriptions of 30 samples from well 93A and 17 samples from well 96B. Fifteen of the samples from well 93A and 4 of the samples from well 96B are from sediment-lined or sediment-filled fractures. All but one of the 47 samples collected were submitted to the Hydrologic Laboratory for analysis. The results of the analyses are included in the following tables:

Table 3, particle-size distribution;
Table 4, statistical grain-size analysis;
Table 5, bulk mineralogy;
Table 6, clay mineralogy, cation-exchange capacity, and carbonate content of well 93A;
Table 7, clay mineralogy, cation-exchange capacity, and carbonate content of well 96B.

Table 2.--Description of samples from wells 93A and 96B

Sample Number	Depth (m)	Description
93A-1	6.13	Joint filling - 7.62 cm thick lt.brown, silty-clay; lt. brown-white carb. in part-joint faces covered w/$CaCO_3$.
		6.74 m - $CaCO_3$ on top of 5.08 cm x 1.27 cm.
93A-2	14.26	Joint partially filled w/lt. brown v.f. silt and clay; evidence of having been sat. w/H_2O. Dry to smooth surface-like clay in suspension.
	19.28	Intersect. vert. and horizon. fract. - clay lines.
93A-3	19.84-21.37	Lt. brown clay lining fractures covered by coarser lt. brown silt appears that clay was deposited in one event followed by deposition of silty material. Will attempt to sample both layers separately for x-ray and isotopes; not enough sample for size anal.
93A-4	19.84	Lt. brown clay, at time of coring sat'd with H_2O as mud ran down side of core diagonal fract. filling. Few geopetal fab. in partially clay-filled vesicles.
93A-5	20.30	Lt. brown clay, sat'd at time of coring. Prob. filling horizontal fracture.
93A-6	21.67	Broken zone in basalt (possible flow contact) - underlain by vert. jointed basalt - gray.
		Lt. brown clay - wet but possibly not sat'd when cored - almost laminated - clay deposited in horizontal joint.
93A-7	22.07	Lt. brown clay in horizontal fract. below vert. fract. unit underlying BG-93A-6. Apparently clay coating fract. and then overlain by silt - 2 filling events.
93A-8	22.68	Lt. brown clay horiz. joints in vesicular basalt.
93A-9	22.98	Lt. brown clay horizon. frac. fillings - laminated also filling vesicles.

Table 2.--Description of samples from wells 93A and 96B (Continued)

Sample Number	Depth (m)	Description
93A-10	23.71	Lt. brown clay w/few pinkish traces - diagonal fracture filling clay filled vesicles above; few below fine laminations.
93A-11	24.38-25.24	50 percent recovery of drive core in sediment bed - dk. brown, moist clayey silt.
93A-12	25.60-25.73	Series of fractures or possibly cinder zone filled w/lt. brown clay; some pinkish material similar to BG-93A-10 - clay beds very wet, if not sat'd w/H_2O at time of coring; pink looks like may be alteration product of clay. Possibly due to heating? Some silt lenses present; suggest interbed.
93A-13	27.13-27.28	Moist, gry, brown gray clay; odor suspiciously like that of soil horizon.
93A-14	28.35-29.75	Lt. brown clay vertical fract. (joint) filling.
93A-15	30.63	Bottom Plastic core tube 29.75-30.63 m missing - sample from bagged-probe within bit - clay/dry/w/rock frags.
93A-16	31.15	Bottom Plastic core tube 30.63-31.15 m missing - sample from bit bag. lt. brown clay; some basalt frags?
93A-17	31.46	Bit sample brown to red clay rounded pebbles w/caliche? coatings.
93A-18	31.46	Top 31.46-32.37 m - dark brown fine sand does not look at all like bit sample poss. cavings.
93A-19	32.37	Bottom bit sample (?) Lt. brown, fine silt, w/rounded basalt pebbles - abundant $CaCO_3$.
93A-20	33.04	Bottom lt. brown fine silt and clay; looks high in $CaCO_3$ few small rounded pebbles. moist; many small basalt frags.

Table 2.--Description of samples from wells 93A and 96B (continued)

Sample Number	Depth (m)	Description
93A-21	33.25	Bottom ox. lt. brown on top; lt. gry on bottom - yellow-green condensation at top of bag. Lt. brown-gray silt-clay; some $CaCO_3$? moist; many small basalt frags.
93A-22	37.58	Concrete which has flowed from concrete well 93. Contains large pebbles.
93A-23	48.37	Vert. fract. lined w/lt gray and some lt. brown clay.
93A-24	55.02	Clay filled diag. fract. lt. brown clay.
93A-25	57.15	Clay filled diagonal and semi-circular fractures - lt. brown clay.
93A-26	69.04	Red brown and clay (baked?) sli. moisture content (condensation in bag); compact, poss. heating phenomena.
93A-27	69.46	Bit sample - lt. red-brown clay - sli. less compacted or baked than -93A-26.
93A-28	69.89	Bottom of core 69.46-69.89 m red-brown clay, moist, appears to be mold growing in bottom of core tube: scrape away bottom portion.
93A-29	70.68	Bottom 70.23-70.68-m core lt. brown clay, few qtz. grains mold on bottom, scraped off - lt. tan to white $CaCO_3$ concretions. Layered clays; poss. organic matter also layered $CaCO_3$.
93A-30	71.08	Bottom of 70.68-71.08 m core bottom of well. Med. brown silt; moldy apparent $CaCO_3$; some weathered basalt frags.
96B-1	10.85	"9-m" interbed - lt. brown, tan, fine silt-clay; $CaCO_3$ (?) coatings on basalt frags. Partially consolidated, no acid react. No $CaCO_3$. Thermal baking, contain holes resembling root tubes in caliches.
96B-2	11.70	Red fine silt-clay; partially consolidated as above/"root tubes" as above; few basalt frags rounded.

Table 2.--Description of samples from wells 93A and 96B (continued)

Sample Number	Depth (m)	Description
96B-3	12.19	Med. brown, fine sand and silt, v. sli. consolidated qtz. 10%± heavy mins. med. well sorted.
96B-4	12.27	As above but higher feldspar content; some portions less well consolidated.
96B-5	30.08-30.51	At 30.51 m contact between basalt and interbed - lt. brown pebbly sediment, rounded pebbles.
96B-6	30.94	Lt. med. gray pebbly sand semi-consolidated to unconsolidated. Contact between gravel-clay ∿35.30 m.
96B-7	35.51	Bottom of core, dk brown plastic clay w/few silt and sediment grains present mold on bottom - removed.
96B-8	37.34	Bottom of core Dk brown, fn. sd., well sorted and rounded ∿35-40% heavy mins.
96B-9	38.77	Bottom of core dk. brown sediment as above possible sli. higher clay content (?).
96B-10	39.56	Clay filled diagonal fracts. in dk gray vesicular basalt, silt, clay and some sd. lt. brown; some evidence of clay material on basalt surfaces; coarser material limited to larger diag. and horizontal fracture; vert. to conchoidal fract. appears to contain only very fine clay.
96B-11	44.74-45.14	Vert. fract. filling, lt. brown clay similar to 96B-12 but apparently finer grained.
96B-12	45.35	Vert. and horizon. fract. fillings above very vesicular dk gray basalt - appears to be contact between two flows??
96B-13	55.35-56.02	Vert. fract. filling appears to be two major filling events: 1) fract. lined and some vesicles filled w/lt tan-buff clay. 2) fract. lined and in some areas filled and some vesicles filled w/med dk. brown fine sd. and silt.

Table 2.--Description of samples from wells 93A and 96B (continued)

Sample Number	Depth (m)	Description
96B-14	65.11	Cinder and clay layer between sli. vesicular basalt and highly vesicular basalt - clay coat., all cinder particles; vert. fract. below bed only sli. lined w/clay.
96B-15	67.45	Top of 1st interbed core red fine-grained silt.
96B-16	66.52	Top of core 68.52-69.31 m red-brown fine-silt.
96B-17	70.01	Bottom of hole brown fine-silt.

Table 3.--Particle-size distribution in percent, for samples from wells 93A and 96B

Sample number	Depth (meters)	Sample type	Clay (<0.004 mm)	Silt (0.004-0.0625 mm)	Very fine sand (0.0625-0.125 mm)	Fine sand (0.125-0.25 mm)	Medium sand (0.25-0.5 mm)	Coarse sand (0.5-1 mm)	Very coarse sand (1-2 mm)	Very fine gravel (2-4mm)	Fine gravel (4-8 mm)	Medium gravel (8-16 mm)	Coarse gravel (16-32 mm)	Very coarse gravel (32-64 mm)
93A-1	5.52-5.58	F	16.1	41.8	14.5	11.2	8.1	5.0	2.3	0.9	0.1	0	0	0
-2	14.26	F				Insufficient	Sample							
-3	19.29	F				Insufficient	Sample							
-4	19.89	F	25.9	17.8	6.6	2.2	2.3	2.5	2.5	4.4	17.2	18.8	0	0
-5	20.30	F	29.8	14.5	1.5	1.9	1.7	0.9	2.9	0.4	13.6	12.9	20.0	0
-6	21.67	F[2]	20.2	7.6	0.3	0.6	0.9	1.8	0.1	2.0	3.1	12.9	50.5	0
-7	22.07	F				Insufficient	Sample							
-8	22.68	F				Insufficient	Sample							
-9	22.98	F(laminated)	51.7	19.4	0.6	0.4	0.4	0.6	0.7	2.1	3.5	20.6	0	0
-10	23.71	F	—— 71.7 ——		1.6	0.5	0.1	0.4	0.7	2.5	3.6	19.0	0	0
-11	24.38	I[3]	23.6	58.7	9.0	5.0	3.1	0.5	0.1	0	0	0	0	0
-12	25.60-25.76	I[3]	62.0	7.1	0.4	0.8	0.2	0.4	0.4	0.6	1.6	2.7	0	23.7
-13	27.13-27.28	I[4]	44.0	14.0	1.9	1.8	1.8	2.2	2.8	9.4	13.8	8.3	0	0
-14	28.35-29.75	F				Insufficient	Sample							
-15	30.63	I	15.7	18.0	6.1	10.8	16.8	12.4	6.4	5.4	4.6	3.8	0	0
-16	31.15	I	12.7	12.4	4.8	6.4	8.9	15.9	10.5	12.5	11.7	4.1	0	0
-17	31.46	I	17.5	16.0	5.9	8.1	11.5	9.6	8.1	9.8	7.7	5.6	0	0
-18	31.46	I(cavings)	—— 0.8 ——		5.4	8.0	23.7	8.6	2.9	0.2	4.2	15.2	30.9	0
-19	32.37	I	13.9	19.7	6.3	13.0	10.4	7.9	3.8	8.6	7.1	5.2	4.1	0
-20	32.98	I	11.1	5.1	3.6	8.0	10.7	4.8	4.4	20.4	18.0	13.8	0	0
-21	33.25	I	7.7	48.9	8.0	6.5	3.1	4.3	3.6	11.3	3.6	3.1	0	0
-22	37.55	F(cemented)	15.6	49.0	4.1	2.0	1.8	2.5	4.0	3.8	10.5	6.7	0	0
-23	48.37	F				Insufficient	Sample							
-24	55.02	F	65.5	8.3	3.2	3.8	2.4	2.1	2.6	1.1	5.1	5.9	0	0
-25	57.15	F	61.3	21.8	0.8	1.4	1.9	2.7	3.5	2.0	2.7	2.0	0	0
-26	69.04	I	18.2	13.4	2.9	5.2	9.1	26.0	25.1	0	0	0	0	0
-27	69.46	I	45.1	24.2	6.8	12.0	11.9	0	0.1	0	0	0	0	0
-28	69.89	I	13.8	42.8	9.1	6.5	7.3	5.2	3.0	8.0	3.3	0.9	0	0
-29	70.62	I	26.8	47.1	6.7	8.1	6.5	2.7	0.1	1.1	0.9	0	0	0
-30	71.08	I	23.3	43.0	7.5	7.8	6.9	4.8	3.8	0.5	2.0	0.4	0	0
96B-1	10.85	I	7.9	31.6	6.2	5.4	5.9	8.4	1.5	2.8	7.1	16.9	6.3	0
-2	11.79	I[3]	8.7	46.8	18.3	14.8	11.3	0.1	0	0	0	0	0	0
-3	12.19	I	4.0	11.1	26.1	38.0	18.7	2.3	0	0	0	0	0	0
-4	12.28	I	4.1	17.9	26.2	36.8	13.7	1.2	0.1	0	0	0	0	0
-6	30.94	I	3.6	4.9	2.4	3.1	4.5	11.6	6.8	12.4	16.7	28.1	5.9	0
-7	35.51	I	72.0	8.7	6.4	7.1	3.2	1.2	1.5	0	0	0	0	0
-8	37.34	I	—— 1.2 ——		19.4	66.6	12.6	0.1	0.2	0	0	0	0	0
-9	38.77	I	7.7	10.8	20.9	27.5	23.9	6.5	0.5	0.1	0.6	1.5	0	0
-10	39.56	F	9.9	39.2	19.6	10.2	2.8	1.5	1.8	1.7	7.8	5.5	0	0
-11	44.74-45.14	F	15.3	46.0	18.2	7.7	2.9	6.1	3.9	0	0	0	0	0
-12	45.35	F	13.2	23.3	9.3	4.6	4.0	4.6	3.4	9.9	20.8	7.0	0	0
-13	55.35-55.96	F	9.3	7.1	42.5	20.4	1.5	2.0	1.3	5.7	4.6	5.5	0	0
-14	65.11	I[3]	9.8	1.5	1.6	2.0	3.7	6.5	13.0	22.1	25.9	13.97	0	0
-15	67.45	I	6.9	40.9	26.3	15.2	9.8	0.8	0	0	0	0	0	0
-16	68.52	I	8.8	43.4	40.8	5.6	0.9	0.5	0.1	0	0	0	0	0
-17	70.01	I	10.0	68.1	17.6	3.3	0.8	0.1	0	0	0	0	0	0

[1] F-fracture fill sample, and I-interbed sample.
[2] Possible flow contact sample.
[3] Sample type questionable.
[4] Possible soil zone sample.

Table 4.--Statistical characteristics for grain-size analyses and specific gravity for samples from wells 93A and 96B

Sample number	Depth (meters)	Median Size (mm)	Sorting Coefficient	Skewness	Kurtosis	Uniformity coefficient	Specific gravity (Gm/cc)
93A-1	5.52-5.58	0.04	3.0	1.6	0.15	55.0	2.77
-2	14.26	Insufficient sample					
-3	19.29	Insufficient sample					
-4	19.84	0.12	41.0	1.7	--	--	2.72
-5	20.30	0.88	67.0	0.05	--	--	2.69
-6	21.67	16.0	50.0	--	--	--	2.72
-7	22.07	Insufficient sample					
-8	22.68	Insufficient sample					
-9	22.98	--	--	--	--	--	2.68
-10	23.71	--	--	--	--	--	--
-11	24.38	0.02	3.1	0.83	--	--	2.72
-12	25.60-25.76	--	--	--	--	--	2.72
-13	37.13-27.28	0.01	--	--	--	--	2.79
-14	28.35-29.75	Insufficient sample					
-15	30.63	0.24	6.0	0.30	--	--	2.68
-16	31.15	0.65	6.4	0.37	--	--	2.72
-17	31.46	0.30	11.0	0.28	--	--	2.68
-18	31.46(cavings)	4.3	7.2	0.37	0.35	0.61	--
-19	32.37	0.22	8.7	1.1	--	--	2.67
-20	32.98	2.2	5.2	0.23	0.26	1229.0	2.76
-21	33.25	0.04	10.0	2.7	0.26	22.0	2.68
-22	37.55	0.02	12.0	14.0	0.07	25.0	3.01
-23	48.37	Insufficient sample					
-24	55.02	--	--	--	--	--	2.69
-25	57.15	--	--	--	--	--	2.74
-26	69.04	0.52	6.9	0.08	0.31	518.0	2.79
-27	69.46	0.01	9.5	5.2	--	--	2.85
-28	69.89	0.05	4.2	2.5	0.06	34.0	2.69
-29	70.68	0.02	5.0	0.52	--	--	2.76
-30	71.08	0.019	6.0	1.5	--	--	2.84
96B-1	10.85	0.22	18.0	3.0	0.24	140.0	2.66
-2	11.70	0.05	2.8	1.0	0.21	17.0	2.71
-3	12.19	0.15	1.7	0.86	0.21	6.2	2.69
-4	12.28	0.13	1.8	0.87	0.23	7.5	2.66
-6	30.94	4.2	4.6	0.30	0.34	65.0	2.77
-7	35.51	--	--	--	--	--	2.60
-8	37.34	0.18	1.3	0.93	0.22	2.2	--
-9	38.77	0.17	2.0	0.91	0.26	32.0	2.70
-10	39.56	0.07	3.0	1.1	0.02	24.0	2.66
-11	44.74-45.14	0.04	2.8	1.1	0.10	47.0	2.82
-12	45.35	0.24	13.0	2.1	--	--	2.80
-13	55.35-55.96	0.11	1.7	1.3	0.018	25.0	2.67
-14	65.10	2.9	2.5	0.70	0.26	251.0	2.99
-15	67.45	0.066	2.4	0.68	0.21	7.6	2.68
-16	68.52	0.06	1.9	0.67	0.29	17.0	2.71
-17	70.01	0.026	3.0	0.57	--	--	2.73

Table 5. Bulk mineralogy for samples from wells 93A and 96B

Sample number	Quartz (percent)	K-spar (percent)	Plagioclase (percent)	Calcite (percent)	Pyroxene (diopside?) (percent)	Clay minerals (percent)	Total (percent)
93A-1	21	≤6	13	7	<11	35	76+
-2	12	≤3	9	15	<13	25	61+
-3	30	4	10	6	13	30	93
-4	19	≤4	11	7	9	30	76+
-5	17	3	12	0	11	40	83
-6	19	≤3	11	0	11	40	81+
-7	22	5	11	0	9	45	92
-8	24	5	13	0	17	40	99
-9	19	≤3	8	0	11	50	88+
-10	26	5	10	0	9	50	100
-11	32	9	13	0	9	30	93
-12	21	3	7	0	9	60	100
-13	16	5	7	0	9	60	97
-14	10	≤2	5	0	4	70	89+
-15	35	≤6	14	2	11	15	77+
-16	33	≤5	13	4	9	15	74+
-17	18	<7	14	≤3	16	25	73+
-18	30	<5	14	0	13	10	67+
-19	32	<8	17	0	16	25	90+
-20	32	<7	17	0	16	25	90+
-21	10	<5	10	13	≤18	20	53+
-22	0	≤5	19	0	24	0	43+
-23	6	<3	15	0	18	30	69+
-24	9	3	9	0	9	60	90
-25	7	3	8	3	12	65	98
-26	17	≤7	11	≤2	18	10	56+
-27	18	≤6	13	≤2	20	15	66+
-28	19	<4	10	0	7	30	66+
-29	11	<4	8	35	<11	10	64+
-30	6	≤3	13	13	20	15	67+
96B-1	29	≤4	12	0	4	30	75+
-2	26	<5	11	0	≤7	5	42+
-3	37	7	13	0	9	25	91
-4	37	7	15	0	11	30	100
-6	28	<6	13	0	13	5	59+
-9	24	≤8	15	0	11	30	80+
-10	27	≤5	12	0	9	30	78+
-11	17	<6	16	0	16	25	74+
-12	20	<5	13	0	13	30	76+
-13	19	<6	13	0	11	20	63+
-14	4	≤4	15	0	20	40	79+
-15	28	9	12	0	11	10	70
-16	24	<6	12	3	9	30	78+
-17	26	≤4	11	0	9	40	86+

Table 6.--Clay mineralogy of selected samples from 93A
(percent of total clay minerals/percent of original bulk sample)

INEL Sample type[1]	INEL Sample number	Depth (meters)	Chlorite	Illite	Mixed layer clays	Montmoril-lonite	Kaolinite	CEC (meq/100gm)	Carbonate content (as $CaCO_3$)
F	93A-1	5.52-5.58	0/0	28/10	25/9	36/13	11/4	17.	2.7
F	-2	14.26	0/0	38/10	33/8	10/2	19/5	12.	14.6
F	-3	19.29	2/<1	45/14	25/8	16/5	12/4	11.	5.0
F	-4	19.89	2/<1	60/18	13/4	11/3	14/4	9.6	0.39
F	-5	20.30	4/2	48/19	26/10	12/5	10/4	15.	0.78
I[2]	-6	21.67	0/0	50/20	22/9	13/5	15/6	27.	0
F	-7	22.07	3/1	49/22	22/10	9/4	17/8	18.	0
F	-8	22.68	0/0	50/20	27/11	12/5	11/4	17.	0
F	-9	22.98	0/0	60/30	12/6	11/6	17/8	19.	0
F	-10	23.71	0/0	47/24	28/14	13/6	12/6	17.	0
I	-11	24.38	0/0	38/11	25/8	25/8	12/4	13.	0
I	-12	25.60-25.76	0/0	48/29	32/19	11/7	9/5	25.	0
I	-13	27.13-27.28	0/0	42/25	32/19	16/10	10/6	21.	0
F	-14	28.35-29.75	0/0	42/29	27/19	12/8	19/13	32.	0
I[3]	-15	30.63	11/2	62/9	23/3	0/0	4/<1	4.2	0.43
I[3]	-16	31.15	15/2	60/9	0/0	11/2	18/3	5.2	1.5
I[3]	-17	31.46	2/<1	43/11	16/4	22/6	17/4	4.9	0
I[3](cavings)	-18	31.46	1/<1	19/2	37/4	38/4	5/<1	6.9	0
I[3]	-19	32.37	0/0	47/12	25/6	12/3	16/4	6.5	0.48
I[3]	-20	32.98	3/<1	33/8	38/10	12/3	14/4	5.6	0
I[3]	-21	33.25	0/0	16/3	37/7	36/7	11/2	14.	11.7
F(cemented)	-22	37.55	0/0	0/0	0/0	0/0	0/0	3.5	1.2
F	-23	48.37	0/0	62/19	0/0	28/8	12/4	3.5	0.70
F	-24	55.02	1/<1	26/16	45/27	18/11	10/6	30.	0
F	-25	57.15	0/0	33/21	30/20	20/13	17/11	36.	2.3
I[4]	-26	69.04	0/0	100/10	0/0	0/0	0/0	7.5	0
I[4]	-27	69.46	0/0	86/13	14/2	0/0	0/0	8.6	0
I[4]	-28	69.89	0/0	97/29	3/1	0/0	0/0	16.	0.31
I[4]	-29	70.62	0/0	58/6	32/3	0/1	0/0	21.	28.8
I[4]	-30	71.08	0/0	44/7	52/8	4/<1	0/0	36.	7.6

[1]F-fracture fill sample, and I-interbed sample.
[2]Sample type questionable.
[3]Sample from 34-m interbed.
[4]Sample from 73-m interbed.

Table 7.--Clay mineralogy of selected samples from 96B
(percent of total clay minerals/percent of original bulk sample)

INEL Sample type[1]	INEL Sample number	Depth (meters)	Chlorite	Illite	Mixed layer clays	Montmoril-lonite	Kaolinite	CEC (meq/100gm)	Carbonate content (as $CaCO_3$)
I[2]	96B-1	10.85	0/0	77/23	23/7	0/0	0/0	18.	0.61
I[2,3]	-2	11.70	0/0	100/5	0/0	0/0	0/0	0.9	0
I[2]	-3	12.19	0/0	60/15	36/9	4/1	0/0	8.8	0.64
I[2]	-4	12.28	0/0	56/17	44/13	0/0	0/0	8.2	0.41
I[4]	-6	30.94	0/0	100/5	0/0	0/0	0/0	2.3	0
I[4]	-7	35.51	0/0	14/10	41/29	39/27	6/4	18.	0
I[4]	-8	37.34	2/<1	23/6	43/11	27/7	5/1	6.3	0
I[4]	-9	38.77	2/<1	27/8	41/12	22/7	8/2	10.	0
F	-10	39.56	3/1	14/4	55/16	19/6	9/3	17.	0.50
F	-11	44.74-45.14	0/0	29/7	52/13	0/0	19/5	13.	0
F	-12	45.35	0/0	52/16	16/5	18/5	14/4	13.	0
F	-13	55.35-55.96	0/0	54/11	8/2	24/5	12/2	13.	0.40
I[5]	-14	65.11	2/<1	44/18	20/8	21/8	13/5	9.7	0
I[5]	-15	67.45	0/0	100/10	0/0	0/0	0/0	13.	0
I[5]	-16	68.52	0/0	37/11	45/14	13/4	5/21	11.	2.4
I[5]	-17	70.01	1/<1	20/8	43/17	28/11	7/3	16.	0

[1] F-fracture fill sample, and I-interbed sample.
[2] Sample from 9-m interbed.
[3] Sample type questionable.
[4] Sample from 34-m interbed.
[5] Sample from 73-m interbed.

Twenty-four thin sections were examined to determine the degree of basalt alteration and of the resulting in-situ clay formation. Particle orientation, alteration products, and the relationship of alteration products to basalt and sediment were evaluated; and are discussed in a following section of this report.

HYDROGEOLOGIC INTERPRETATIONS

SAMPLE PARTICLE-SIZE DISTRIBUTION

The particle-size data from both well 93A and well 96B show that fracture filling sediments are generally finer grained than interbed sediments. This is as expected, whether material formed in situ or introduced by infiltrating water, the finer fraction is deposited in the fractures preferentially. If the clay-size material were formed in situ, the coarser material present would be residual grains of minerals from the altered basalt. Sediment transported by infiltrating waters would probably contain some coarser silt or fine sand transported during major recharge events. This transportation of coarse silt or fine sand will be considered in the discussion concerning thin-section analysis of sediment materials.

Several samples from each well contained significant quantities of gravel. In the samples taken from interbeds, the gravel is rounded as is characteristic of material transported by streams. Some rough gravels, observed in samples of fracture-filling material, were fragments of the fractured basalt and were not considered to be part of the sedimentary fracture-filling component. Samples containing such gravels are 93A-4, 93A-5, 93A-6, 93A-9, 93A-10, 93A-24, 93A-25, 96B-10, 96B-12, and 96B-13. A size distribution representative of sedimentary lining or filling a fracture may be concluded if the presence of particles coarser than approximately 1 mm is deemed not representative of material (0.5 mm was the coarsest particle seen in fracture-filling material in thin section).

SAMPLE BULK MINERALOGY

The bulk mineralogy analyses indicate that quartz, plagioclase feldspar, potassium feldspar, pyroxene (diopside?), clay minerals, calcite, and an iron oxyhydroxide are the chief mineral constituents of the sediment interbed and fracture fillings. Olivine [$(Fe, Mg)_2SiO_4$], though not positively identified in these samples because of interference by other peaks on x-ray diffraction patterns, may be present as a coating on discrete grains. A coating on the grains imparts a reddish color to many interbed samples, particularly those of the 73-m interbed. The presence of abundant iron in samples causes adsorption of x-rays and thereby causes problems with x-ray resolution and the interpretation of the x-ray diffraction patterns. This may account for "total percent" determinations for bulk samples being less than 70 percent in the 73-m interbed samples from well 93A (table 5).

Sources of calcium in the sediment include a pyroxene, identified in the Hydrologic Laboratory by x-ray diffraction as diopside [$CaMgSi_2O_6$], and the calcic plagioclase feldspar labradorite [$(Ca_{0.6}Na_{0.4}) Al_2Si_2O_8$]. Previous work (Barraclough and others, 1976) identified the pyroxene as augite [$Ca(Mg, Fe, Al) (Al, Si_2) O_6$], probably a correct conclusion. Potassium in the system could be derived from the breakdown of potassium feldspar ($KAlSi_3O_8$), but would be rapidly immobilized by incorporation into the illite or illite-montmorillonite mixed-layer clay structure.

The abundance of the Fe^{+}-rich minerals and the Fe^{+}-rich oxides suggests that nontronite [$Na_{0.60}Fe^{3}_{4}(Si_{7.34}Al_{0.66}) O_{20}(OH)_4$] might be the expected smectite (montmorillonite) clay mineral formed in this environment. Calcite was observed in some of the samples. Its presence will be discussed in the section concerning determination of carbonate contents.

SAMPLE CLAY MINERALOGY

One of the primary objectives of this study was to determine the possibility of clay-mineral transport through or within sediment beds; therefore, it was necessary to determine what methods may be used to trace clays through the unsaturated zone. Interbed samples were examined closely for clay-mineral distribution to determine the relationship between the clay-mineral contents of sedimentary interbeds and the underlying fracture fillings.

Much of the illite found in sediments is of detrital origin. Some, however, may have been formed by the leaching of potassium from muscovite. Thus, a muscovite/illite mineralogy would be partially replaced by smectite layers producing an expandable mixed layer of clay. If degraded illite is introduced into a high potassium environment, it will fix potassium and become non-expandable illite.

The presence of more than trace quantities of smectite suggests several geochemical characteristics of the environment:

1) high Si:Al ratio,
2) relative abundance of Na^+, K^+, Ca^{++}, and,
3) a low hydrogen ion activity; i.e., pH in the range 7 to 10.

These conditions suggest a geologic environment in which 1) there is less atmospheric precipitation than potential evaporation, 2) minerals hydrolyze and dissolve when sediments are wet, and 3) upon evaporation of water, cations such as Na^+, K^+, and Ca^{++} precipitate with aluminosilicates forming smectites.

The near absence of kaolinite is explained by the aridity of the environment. Kaolinite forms where high rainfall leaches cations and much of the silica from an alumino-silicate parent material. The lack of kaolinite is further explained by the paucity of organic matter in the sediment. The decay of high levels of organic matter would produce high hydrogen activity--that is, a pH less than 7. High hydrogen activity would lead to a high aluminum to silica ratio, a characteristic of kaolinite.

The clay mineralogy of sediments from the different interbeds may be distinctive enough to permit a correlation of clay interbed mineralogy with the mineralogy of sedimentation in fractures underlying those sedimentary beds. The 9-m interbed, present only in well 96B, contains only illite and mixed layer, illite-montmorillonite clay, with an average composition of about 65 percent illite and 35 percent mixed-layer clay. This suggests that one of the following conditions existed during the deposition of this interbed:

1) the time of exposure or the amount of precipitation was insufficient to alter more than minor amounts of illite to mixed-layer clays or montmorillonite, or

2) significant thermal alteration of clay minerals in this thin layer of sediment occurred as it was overridden by an advancing basalt lava flow.

It is believed that the surface was exposed only long enough for a thin sediment to develop and that the mineralogy of the sedimentary unit was altered by the high temperature associated with the overriding lava flow.

Judging by the distribution of clay mineral types in the original bulk sample, the clay mineralogies of the 34-m sedimentary interbed in wells 93A and 96B are quite similar. The kaolinite is less than 4 percent in any sample; the smectite content in sample 96B-7 is less than 7 percent; mixed-layer clays, less than 13 percent; and illite, less than 16 percent (tables 6 and 7). The chlorite content is less than 2 percent in all the samples.

Variations which may be significant occur in the clay mineralogy of samples from the 73-m sedimentary interbed. In well 93A this unit contains no kaolinite, no chlorite, and one percent or less of montmorillonite (table 6). Mixed-layer clays are less than 8 percent and illite ranges from 6 to 29 percent. In well 96B this interbed contains less than 5 percent kaolinite, less than 1 percent chlorite, less than 11 percent smectite, less than 17 percent mixed-layer clays, and 8 to 18 percent illite (table 7). In general, the clay fraction of samples with the lowest total clay content consists of illite and little else.

SAMPLE CATION-EXCHANGE CAPACITY

Cation-exchange capacity (CEC) is a measure of the ability of a material to remove cations from solution by exchanging them for cations held loosely within the structure of the material. Measurements made on all samples of cation-exchange capacity range from 0.9 to 36 meq/100 gm (tables 6 and 7). The sample with the CEC of 0.9 meq/100 gm, 96B-2, contained 5 percent illite, the only clay mineral present. Figure 5 is a plot of cation-exchange capacity (CEC) versus percent expandable clay for the interbed samples. The percentage of expandable layers in the mixed layer clays was not determined and was assumed to be 50. As we expected,

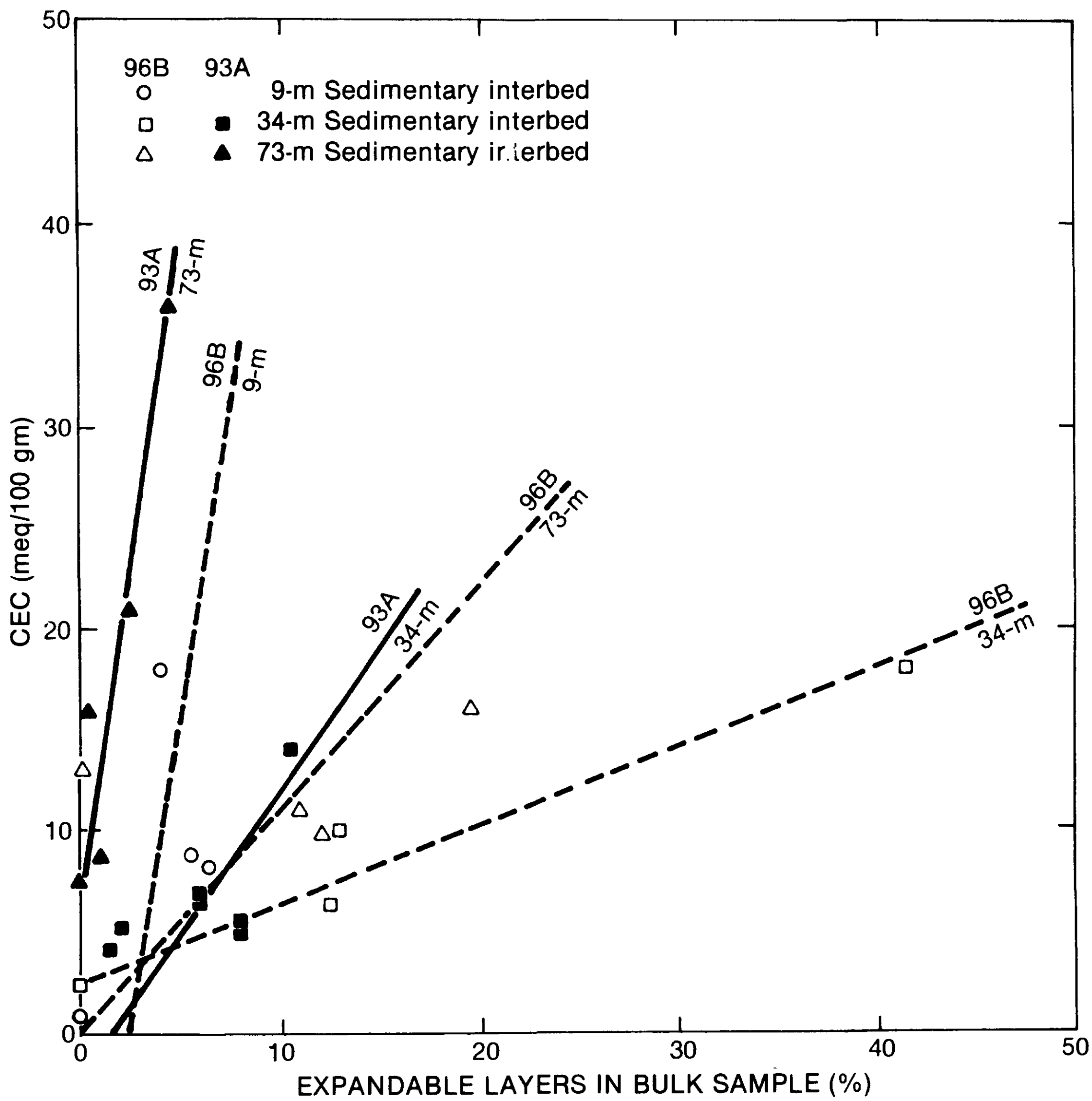

Figure 5.--Relationship of cation-exchange capacity (CEC) to percent expandable-clay layers in bulk sample.

the cation-exchange capacity increases as the percentage of expandable layers in the clay increases. There appears, however, to be no correlation between the same sedimentary interbed that is present in both wells.

The cation-exchange capacities of clay minerals are well known. Table 8 shows the ranges of cation-exchange capacities for various materials. Zeolites, which may be present but have not yet been identified in samples from the INEL, can have cation-exchange capacities in excess of 230 meq/100 gm (Birkeland, 1976). Work on strontium by Hawkins and Short (1965) and by Tamura (1964) suggests that in the presence of abundant sesquioxides (particularly Fe_2O_3) in the environment, there is greater sorption than that predicted by pertinent equations. Samples 93A-28 and 96B-1, both of which diverge from the trend (fig. 5) delineated by other samples from those interbeds in each individual well, are both high in iron-oxide content; this may, in part, be the cause of the anomalously high cation-exchange capacity. These two samples also contain only illite and mixed-layer illite-montmorillonite. Sample 93A-28 contains 29 percent illite and 1 percent mixed layer; sample 96B-1 contains 23 percent illite and 7 percent mixed layer, both in the bulk sample.

Table 8.--Representative cation-exchange capacities for various materials (Birkeland, 1976; from Carroll, 1959, and Grim, 1968)

Material	Approximate cation-exchange capacity (meq/100 gm-dry weight)
Organic matter	150-500
Kaolinite	3-15
Halloysite	5-10
Hydrated halloysite	40-50
Illite	10-40
Chlorite	10-40
Montmorillonite	80-150
Vermiculite	100-150+
Allophane	25-70
Hydrous oxides of aluminum and iron	4
Feldspars	1-2
Quartz	1-2
Basalt	1-3
Zeolites	230-620

SAMPLE CARBONATE CONTENT

The carbonate content of all 47 sediment samples was determined. The carbonate content as a weight percent $CaCO_3$ ranged from zero to 28.8 percent (tables 6 and 7), with the greatest accumulations mostly occurring in the surficial sediment. Accumulation of secondary calcium carbonate (caliche) in soils or surficial sediments provides information about the environment at the time that the sedimentary unit was exposed at land surface.

Pedogenic secondary calcium carbonate in a sediment indicates that the unit was exposed at land surface for a significant period of time and that the rainfall generally ranged from about 38 to 64 cm per year while the carbonate was being deposited. The approximate length of time sediments were exposed can be determined from the amount of $CaCO_3$ deposited, whereas the depth of carbonate accumulation in any one soil type is related to the amount of rainfall (Arkley, 1963).

It may be possible, by examining the accumulations of carbonate in the surficial sediment and in the sedimentary interbeds, and by assuming that the carbonate accumulation started after deposition of the beds, to discover information about the climate during the time of interbed deposition and about length of exposure of the sediment surface to the atmosphere by measuring the depth of major carbonate accumulation. Carbonate accumulations have been noted at depths of 0.5 to 3.7 m below the top of various sedimentary units (fig. 6).

Carbonate accumulations have been noted on waste drums in the Early Waste Retrieval (EWR) and Initial Drum Retrieval (IDR) pits at the Radioactive Waste Management Complex (M. R. Dolenc and T. G. Humphrey, oral commun., 1977). This observation indicates that sufficient water has been present in the RWMC sediments in the last 10 to 20 years to dissolve and reprecipitate calcium carbonate in the soil, and that solution-reprecipitation has occurred.

THIN-SECTION ANALYTICAL OBSERVATIONS

Twenty-four thin sections were examined to determine the mode of emplacement of the sedimentary material within the basalt flows. Seventeen of the thin sections were from well 93A and seven from well 96B. Photographs showing the basalt-sediment interface were made from some thin sections.

Thin-section analysis indicates that only minimal alteration of the basalt minerals has occurred. In several sections there is the suggestion of a decrease in the amount of amorphous iron-oxyhydroxide mineralization with increasing distance away from a fracture surface. Commonly there is a thin (less than 100 μm) clay-mineral layer coating the basalt-fracture surface, with coarser material filling the remaining fracture space. Some fracture-filling material grades in sizes up to about 500 μm, but most is less than 250 μm. Where coarse material (sand) is present, there is commonly only minimal evidence for particle orientation, indicating that the particles settled from water. Many of the coarser grains are angular which indicates that minimal abrasion occurred during transport.

Thin section 93A-24.3-1 (figs. 7 and 8), taken of material from a depth of about 7.4 m in well 93A, shows amorphous silica with radiating texture. Drusy calcium carbonate has been precipitated in indentations on the amorphous silica surface. This indicates that the silica was

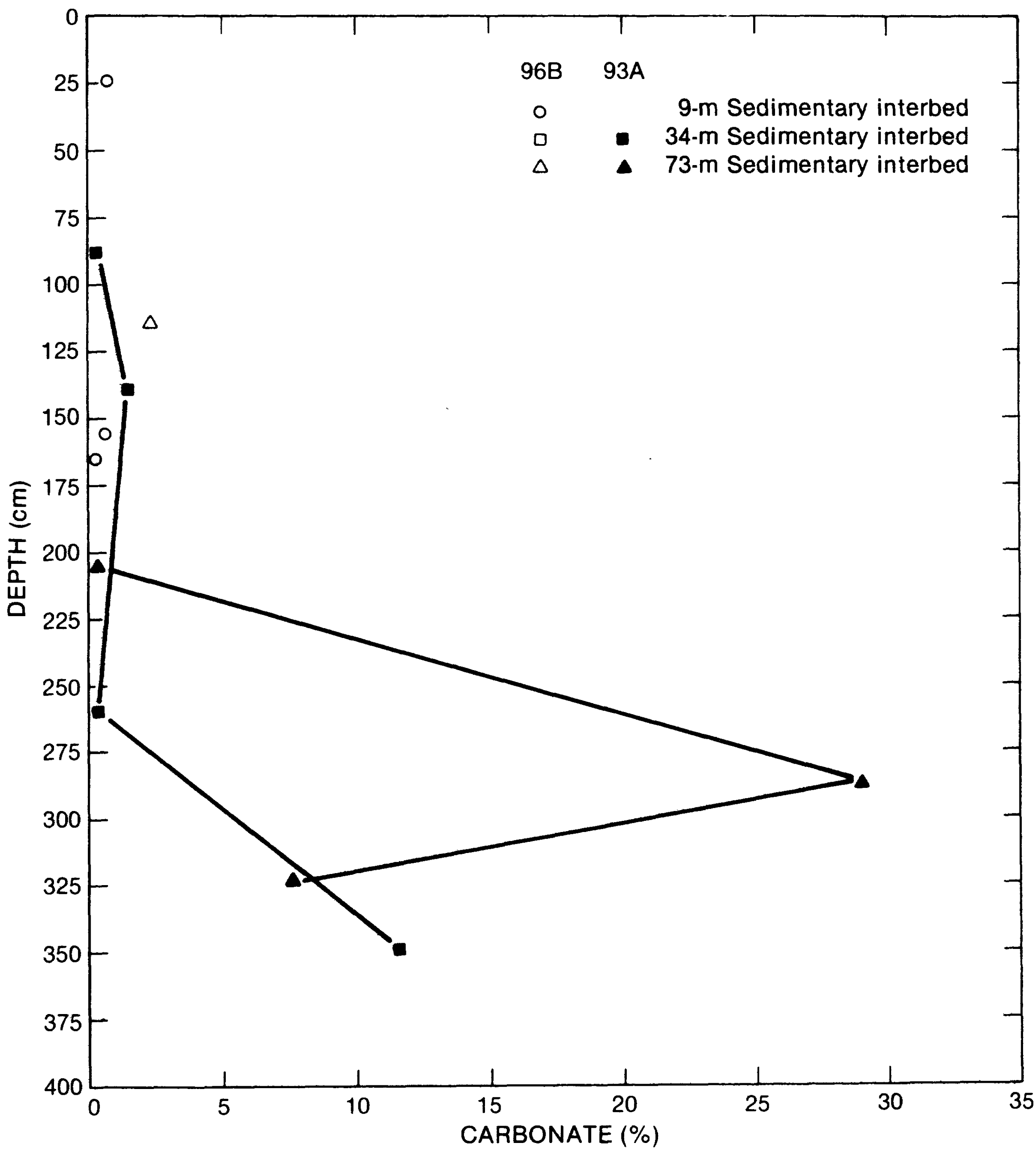

Figure 6.--Relationhsip of carbonate content of sediment to depth beneath sediment surface.

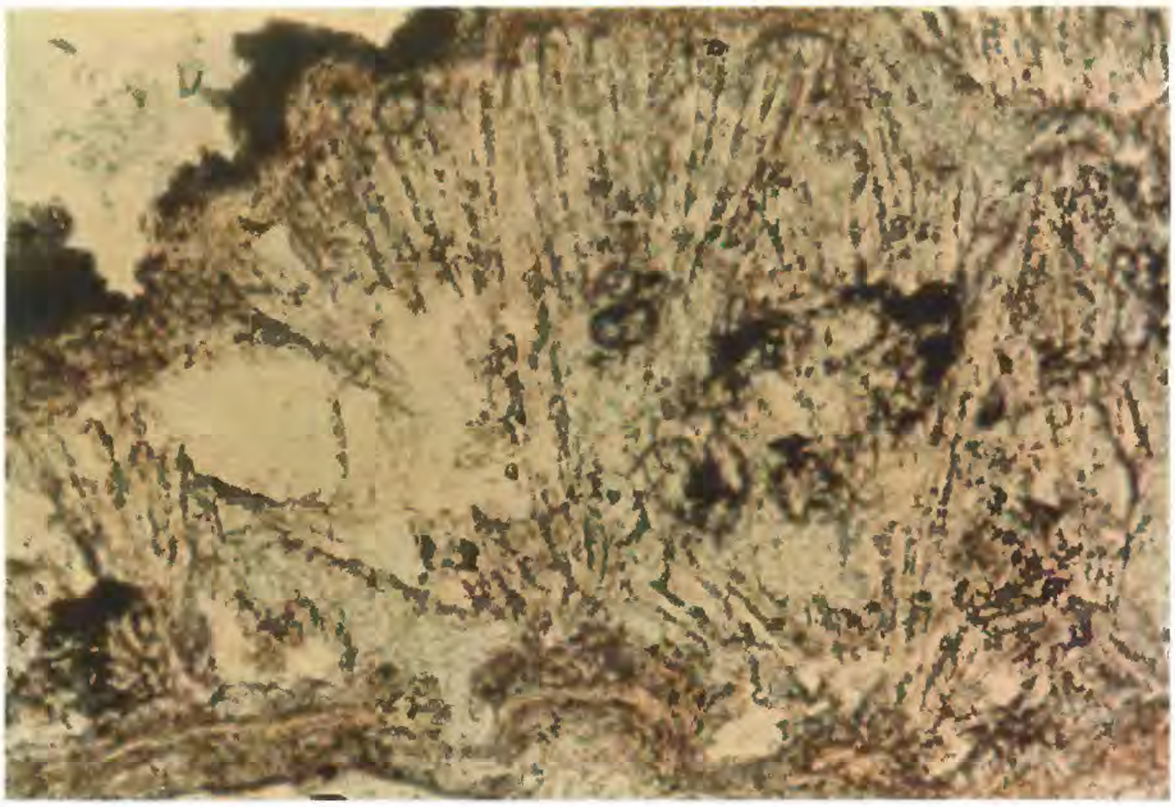

Figure 7.--Photograph of thin section 93A-24.3-1, showing layered and radiating secondary silica overlain by calcium carbonate druse.

Figure 8.--Same as Figure 7-rotated 90°.

precipitated within the uppermost basalt flow, at a depth of approximately 3.1 m below the top of the flow, before sufficient surficial sediment was deposited to be transported down the fracture, and precipitation of carbonate post-dates that of the silica.

Sequential sedimentation events have been inferred from features in several thin sections (from materials at depths of about 22.1, 21.7, 6.7, and 6.1 meters in well 93A, for example). These sections commonly show a series of thin clay layers overlain by an accumulation of randomly oriented coarser particles (silt to fine sand) in a clay matrix. This sequence suggests a series of minor recharge events in which water carried only suspended clay particles followed by a major recharge event such as a flood which transported coarse silt and fine sand as well as clay through fractures to some depth. Thin section 93A-7 (fig. 9) of material at a depth of about 22.1 m, illustrates such an occurrance.

Desiccation features, observed in fracture-filling material in several thin sections (from depths of about 23.3 and 25.6 meters), indicate that significant periods of time elapsed and climatic changes may have occurred between pulses of recharge.

Thin section 93A-25 (of cored material at a depth of 57.15 m) shows sparry calcite precipitated on layered clay (fig. 10). A rim of opaque minerals, adjacent to the sediment-basalt interface,and extending about 50 μm into fine clay material (figs. 11 and 12) may be a product of basalt alteration.

Thin section 96B-86.9 (from cored material at a depth of about 26.5 m in well 96B) shows some diapir-like structures, up to 55 μm high, extending into fine sediment from an iron-oxyhydroxide weathering rind (figs. 13 and 14).

Thin sections show that, with the exception of silica, iron oxyhydroxide, and carbonate chemical precipitates, most of the sedimentary material present in fractures in the basalt is detrital and has been deposited by infiltrating water. Most of the recharge events were minor, only enough water to carry fine detrital clay particles in suspension. This accounts for the thin clay layers observed in several thin sections Rare major recharge events (such as floods) moved sediments containing much coarser (up to 500 μm) particles. Coarse particles are usually deposited in a matrix of finer material with random orientation.

Chemical precipitates of silica (figs. 7 and 8), carbonate (figs. 7, 8, and 10), and the iron oxyhydroxide rinds (figs. 11, 12, 13, and 14) indicate that some mineral alteration may have occurred in situ.

MEGASCOPIC ANALYTICAL OBSERVATIONS

One observation made in the core of well 93A deserves special mention. A fracture at a depth of 53.8 m contained approximately a centimeter of commercial cement, probably originating from the cementing of well 93 approximately 3 m away (see fig. 2). The presence of cement

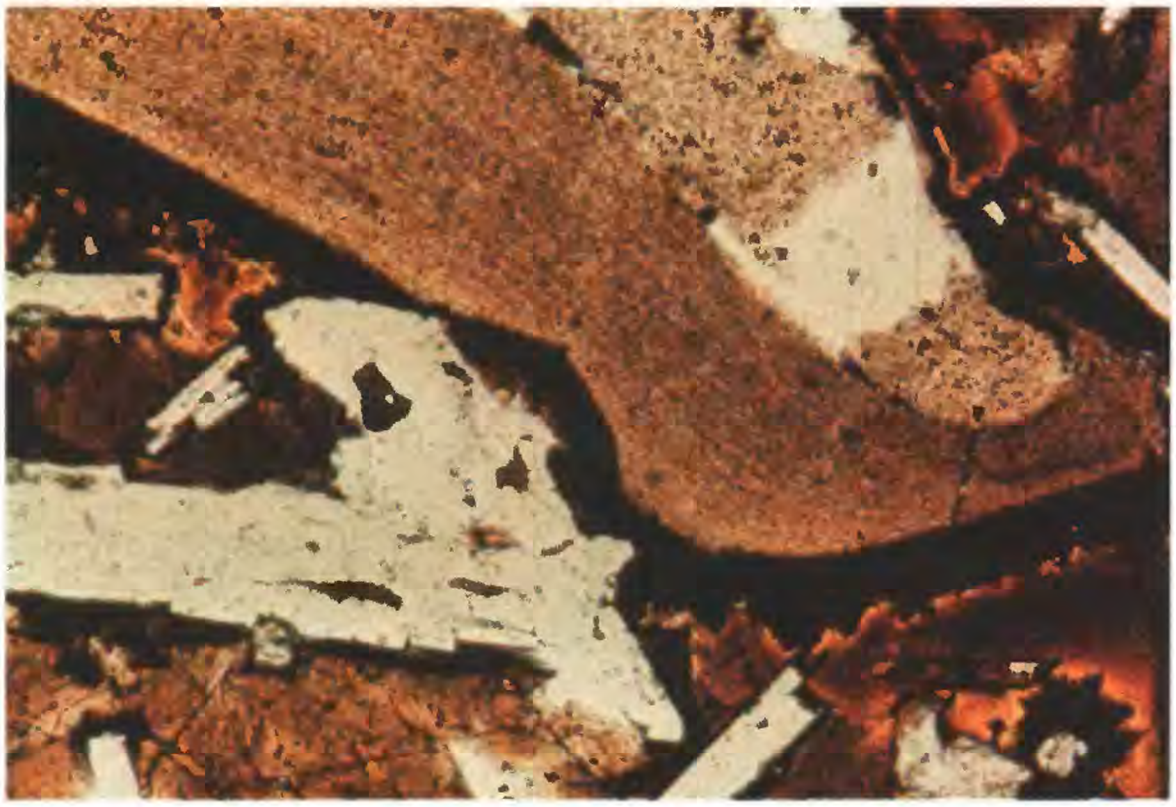

Figure 9.--Photograph of thin section 93A-7, showing layered clay sediment overlain by coarser material suggesting numerous minor recharge events followed by a major recharge event (flood?).

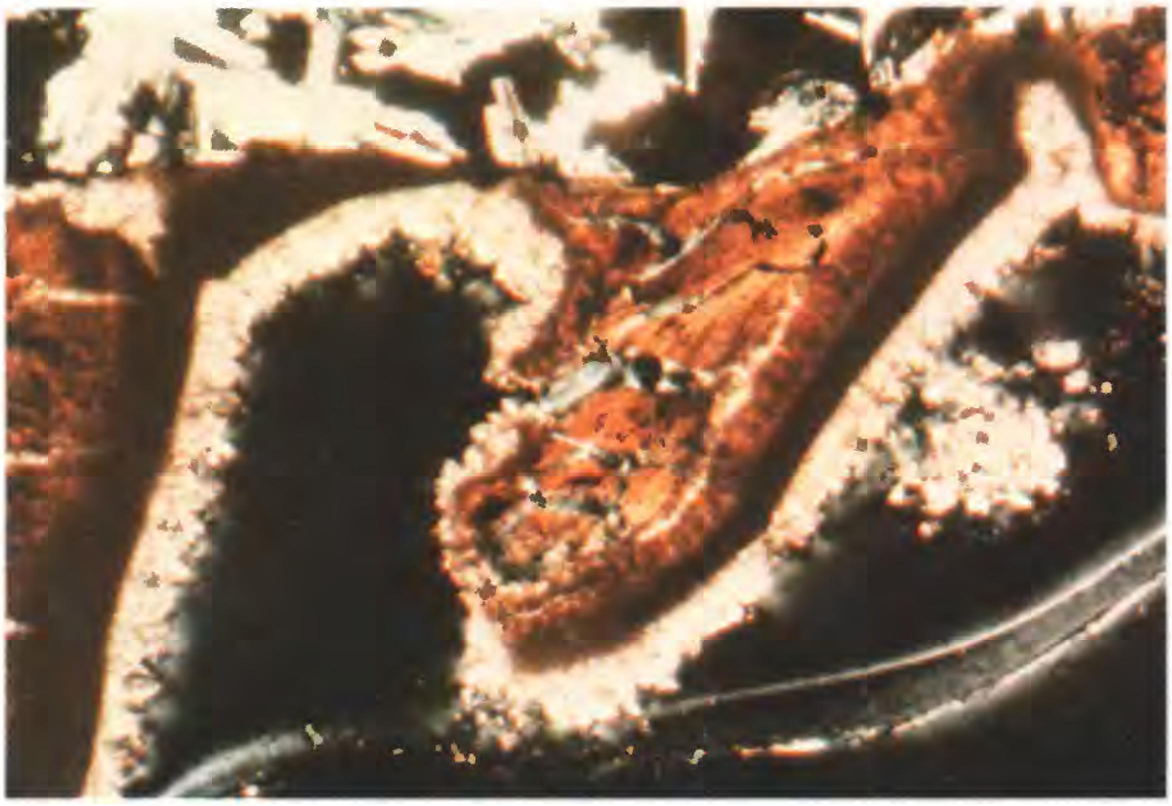

Figure 10.--Photograph of thin section 93A-25, showing fine sparry calcite precipitated on clay drapes on the top surface of a diagonal fracture.

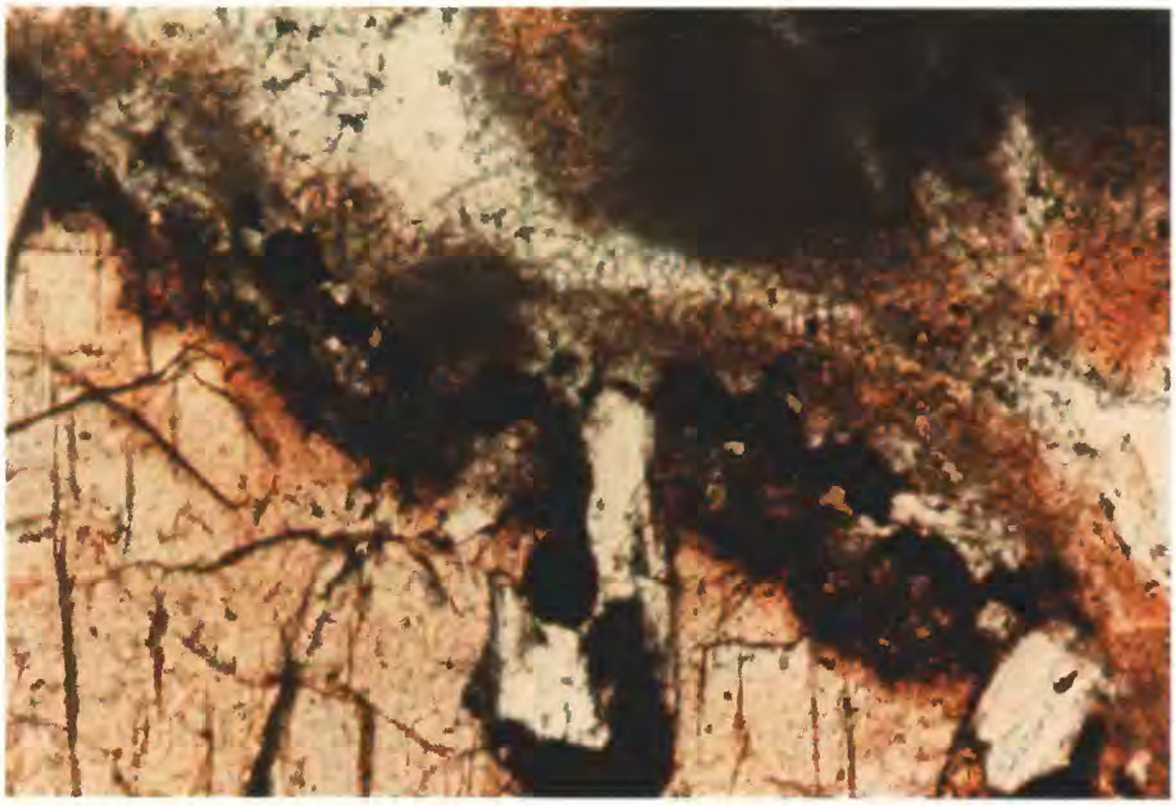

Figure 11.--Possible alteration displayed by development of band of opaque mineral residue paralleling filled fracture surface approximately 50 μm into fine clay material (from thin section 93A-25 photograph).

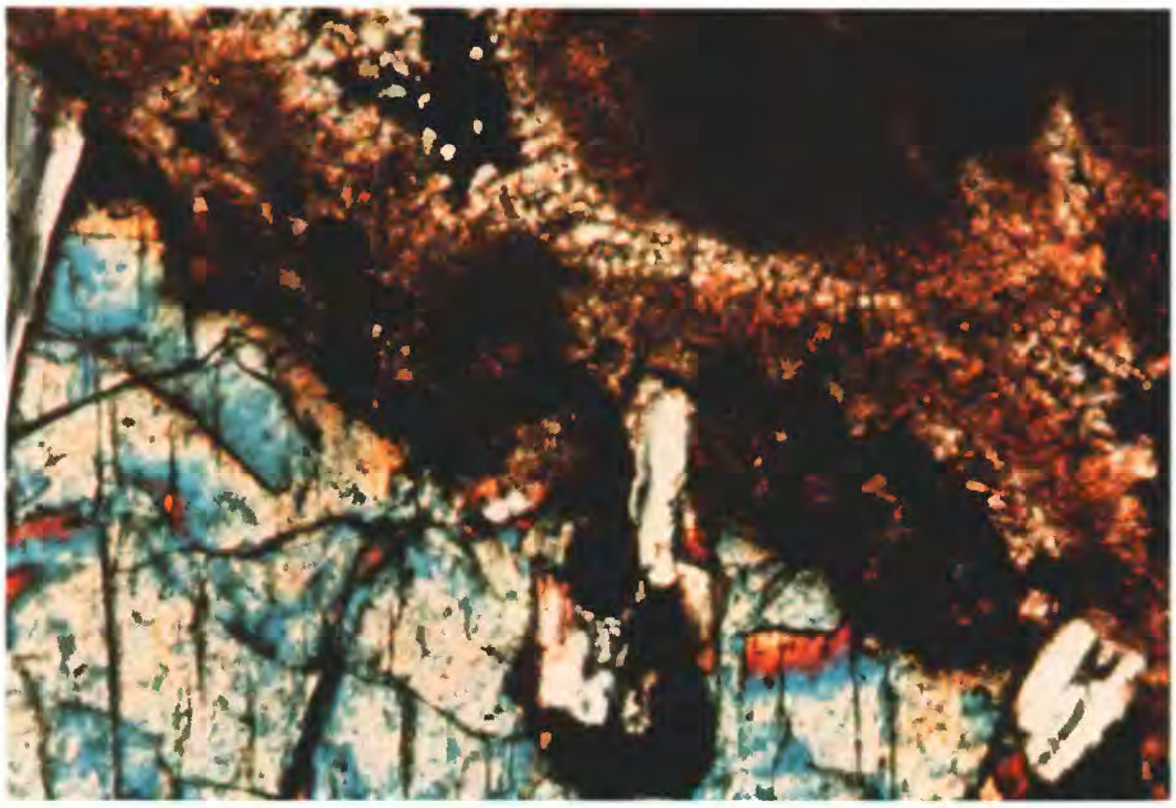

Figure 12.--Same as figure 11-crossed nicols.

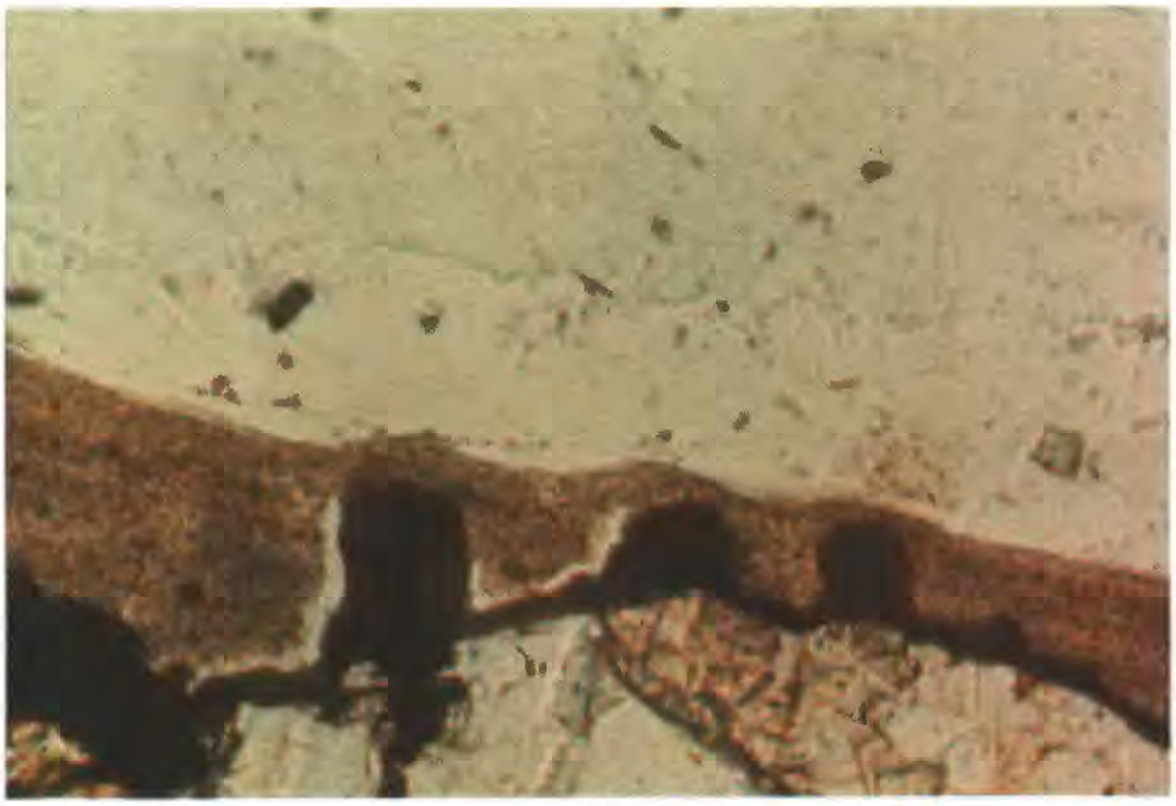

Figure 13.--Photograph of thin section 96B-86.9, showing diapir-like structures on fracture surface, covered with layered clay sediment.

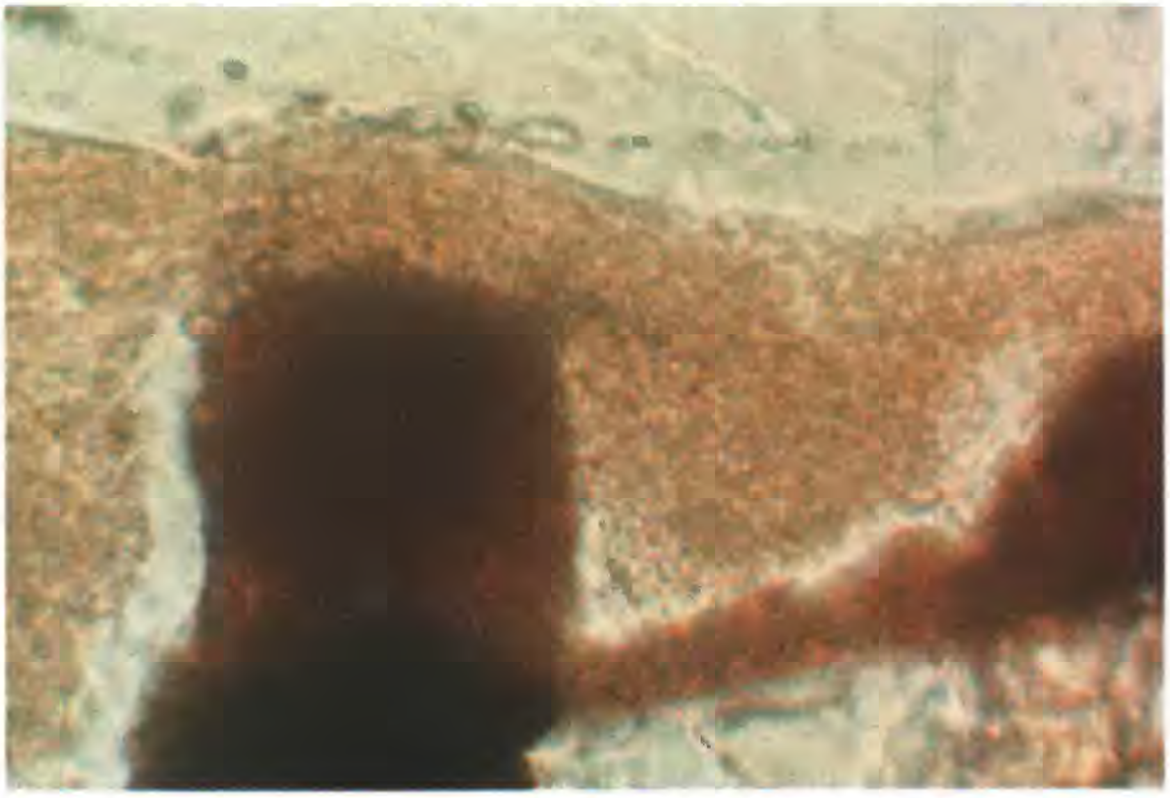

Figure 14.--Same as Figure 13-higher magnification.

with no included sediment indicates that open fractures occur at least 53.8 m below the surface. If such fractures occur in systems of significant horizontal or vertical extent, they could permit movement of sediment bearing water with ease.

CONCLUSIONS

Preliminary conclusions have been drawn from examination of the data and observations presented herein:

1) Each of several basalt flows observed in the shallow subsurface was exposed at the surface long enough to be partially covered by alluvial and eolian sediment and to permit the development of calcium carbonate accumulations in that sediment.

2) On the basis of reconnaissance studies of clay mineralogy, it appears that it may be possible to characterize some portions of individual sedimentary interbeds on the basis of their unique clay-mineral content.

3) The accumulation of major carbonate horizons within sedimentary units, and the depth of these horizons, permit an estimate of the amount of annual precipitation and, therefore, an inference of the climate while a unit was being formed. Caliche (secondary calcium carbonate) accumulations form best under climatic conditions supplying between 25 and 55 cm of water annually.

4) Cation-exchange capacity (CEC) measurements indicate that the expanding clays in the sediments have potential for the removal of uncomplexed cationic radionuclides from solution as they move through the sediment.

5) Thin-section analysis indicates that limited basalt alteration has occurred <u>in situ</u>, but that most of the sedimentary lining and filling of fractures is the result of water-borne sedimentation. Layers of oriented clay particles overlain by disoriented coarser material suggest a series of minor recharge events followed by a major recharge event to fill the fractures.

6) The presence of cement fillings in fractures in well 93A, presumably resulting from the plugging of well 93 (3 m away), shows that fractures occurring at depths of tens of meters may not be sediment filled. Open fractures would permit the transport of coarse and fine material and fluid through the system with ease.

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