PRELIMINARY ANALYSIS OF CLAY GOUGE FROM A WELL IN THE SAN ANDREAS FAULT ZONE IN CENTRAL CALIFORNIA

Richard Liechti
Mark D. Zoback

U.S. Geological Survey
Menlo Park, California

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INTRODUCTION

Drilling into the San Andreas fault zone has begun in central California as part of the U.S.G.S. program of fault zone studies. The purpose of drilling into the fault zone is threefold. First, it will allow recovery of material from depth in order to determine the composition of both solid and fluid phases. Second, it will allow determination of the physical state of the fault zone, that is, the state of stress, pore pressure, and temperature. Finally, it will allow emplacement of instruments at depth in the fault zone for monitoring experiments related to short-term earthquake prediction.

In an attempt to drill to the depth of earthquake focii, the initial drill site was chosen at a locale known as Dry Lake Valley (Fig. 1). Although the entire central section of the San Andreas fault is characterized by moderate seismicity and aseismic creep, Dry Lake Valley has particularly shallow earthquakes as well as a fairly high creep rate (18–20 mm/year). Figure 2 is a longitudinal section along the San Andreas fault. The high precision earthquake locations shown are magnitude one or greater events that occurred in 1973–1975 (from W. Ellsworth, pers. comm.). The depth estimates are accurate to about ± 0.5 cm. It is obvious from the figure that earthquakes in the section of the fault near the well are quite shallow.

SAMPLE ANALYSIS

Samples used in this study were obtained by side-wall coring. This usuallv yielded intact cylindrical samples 2.5 cm in diameter and 4.5 cm long. Samples were taken every 4.6 m from depths between 33.5 m and 284.7 m. Drilling ceased and the hole was abandoned when natural gas was encountered at a depth of 354 m. With the exception of poorly consolidated sedimentary samples from the bottom of the hole, the samples were primarily (>80%) composed of clay gouge. The clays were analyzed for composition using x-ray diffraction techniques.

Samples were prepared in accordance with established methods (J. A. Bartow, pers. comm., 1971; Cibbs, 1971). The steps basically consisted of 1) disaggregating 1.5–2.0 g of sample in 100 ml of distilled water with an ultrasonic probe: 2) allowing the sample to set for 43 minutes for particles >2µ in size to settle out; 3) eyedropping the resulting suspension onto an

AlSiMag disk. A suction was applied to the bottom of the disk in order to draw the water through the disk and leave a uniform layer of the sample deposited. Each sample was then air dryed in a dust-free environment and x-rayed in a series of four steps (Norman, pers. comm.; Schultz, 1964; Pierce and Siegel, 1969). These steps are illustrated in Figures 3a-d (the shaded peaks in these figures correspond to the AlSiMag sample holder) and can be summarized as follows:

Step 1 - Air dryed sample is x-rayed (Fig. 3a). Prominent peaks are present corresponding to kaolinite (12.40) and montmorillonite-chlorite (6°) and chlorite-kaolinite (25°). Chlorite-illite (18.6°) and illite (8.7°) peaks are also present.

Step 2 - Sample is heated in ethyleneglycol atmosphere at 60° C for 4-48 hours before being x-rayed (Fig. 3b). Swelling of the montmorillonite clays causes peak shift from 6° to 5.2°. A chlorite peak at 6° is also now apparent.

Step 3 - Sample is heated at 400° C for 1 hour before being x-rayed (Fig. 3c). Swelled montimorillonite collapses to 8.7° and reinforces the illite peak.

Step 4 - Sample is heated to 5500 C for 1¼-1½ hours before being x-rayed (Fig. 3d). This destroys the kaolinite (12.4°) and further separates the chlorite from montmorillonite.

The procedure for quantitative analysis was taken from Schultz (1964) and Pierce and Siegel (1969) and is based on measurement of peak heights and areas. Areas were determined in the manner suggested by Schultz (1964). Results of the quantitative analyses is tabulated in Table 1 and are shown graphically as a function of depth in Figure 4.

DISCUSSION

The presence of clay gouges in the San Andreas fault has considerable significance with respect to the fault's mechanical behavior. Zoback and Byerlee (1976) showed that the strength of granular aggregates (crushed granite) under pressure was high and essentially the same as the frictional strength of intact materials. The strength of montmorillonite clay, however, is apparently quite weak (Byerlee, 1978; Wang et al., 1979) and if ubiquitous, this could drastically affect the strength and deformation character of the fault zone. Wu et al. (1975) discuss the distribution of clay gouges in the San Andreas system and their possible origin. They cite evidence that the origin of such clays is probably not shallow (after Waters and Campbell, 1935) and argue that based on the age of the San Andreas system (probably > 50 my) and reasonable erosional rates (0.1 mm/year) that near surface material may represent gouge formed at about 5 km. Without further data, however, the question of the composition of the San Andreas fault and the effect of composition on mechanical behavior will remain unresolved.

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TABLE 1

Dry Lake Valley Hole No. 1

Composition of clays by percentages

Depth (m)	Montmorillonite	Kaolinite	Illite	Chlorite
33.5	69	19	11	3
93.0	71	11	26	2
106.7	47	34	9	10
125.0	33	49	7	11
152.4	43	39	8	11
211.8	48	32	8	13
248.4	38	46	6	10
282.6	21	53	12	16
284.7	32	42	11	15

Note: Due to uncertainties in determining area under peaks, each of the above values is accurate to only ± 10%.

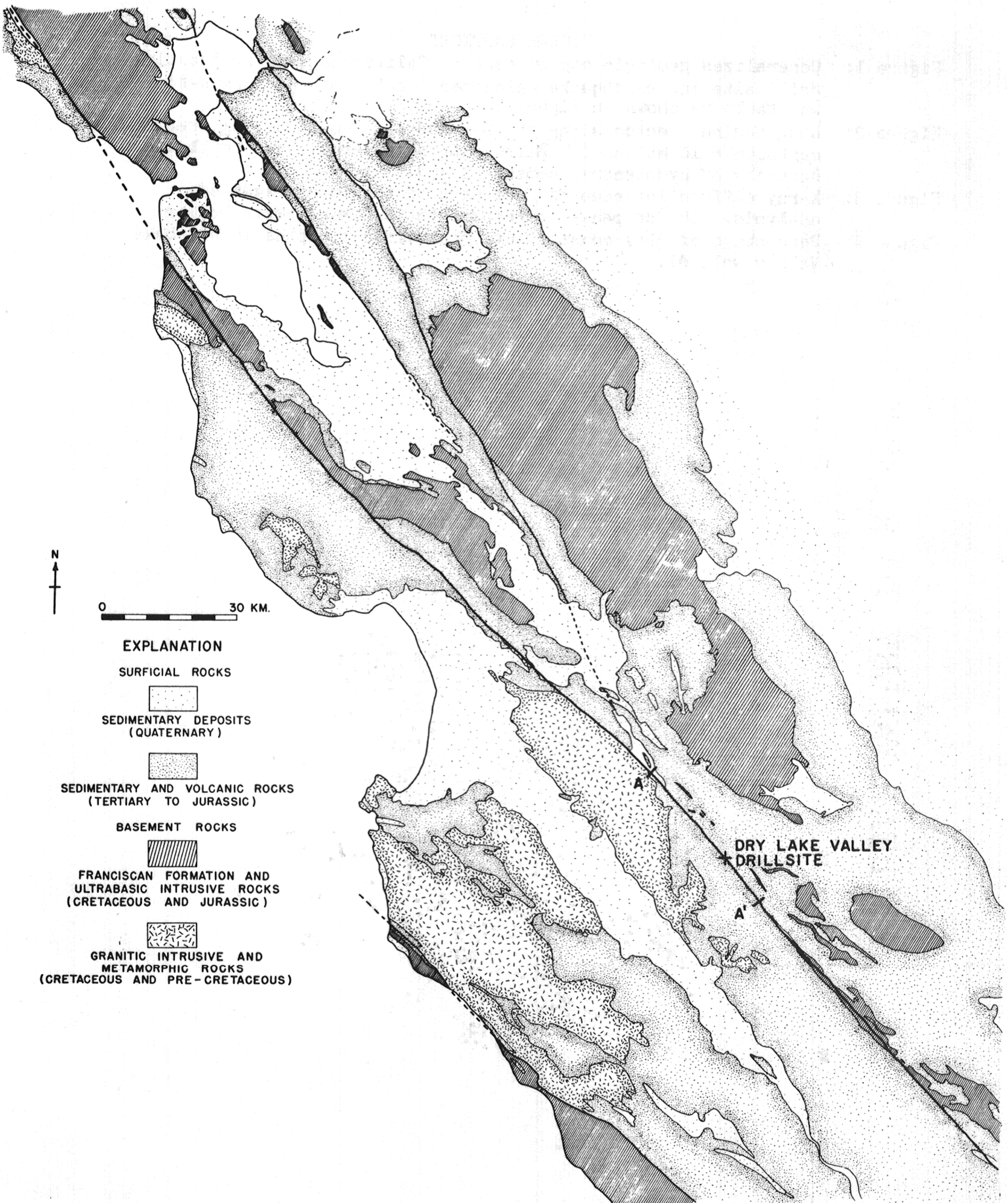
FIGURE CAPTIONS

Figure 1: Generalized geologic map of central California showing location of drill site and earthquake epicenter locations. Section A-A' along the fault is shown in Figure 2.

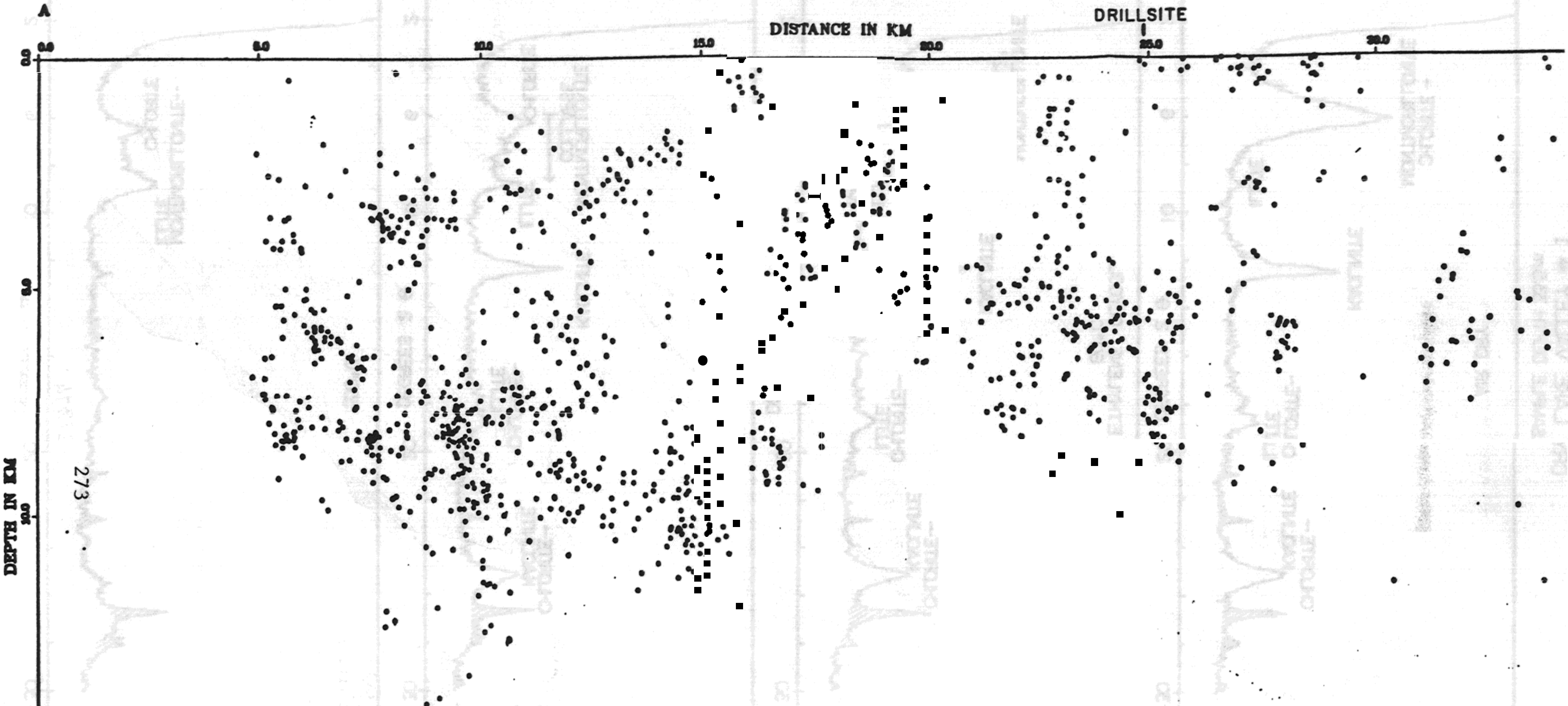
Figure 2: Longitudinal secton along the San Andreas fault showing precise earthquake locations (W. Ellsworth, pers. comm.) and drill site. Accuracy of hypocentral depths is ± 0.5 km.

Figure 3: X-ray diffraction records from each of the four stages of analysis. Shaded peaks correspond the AlSiMag sample holder.

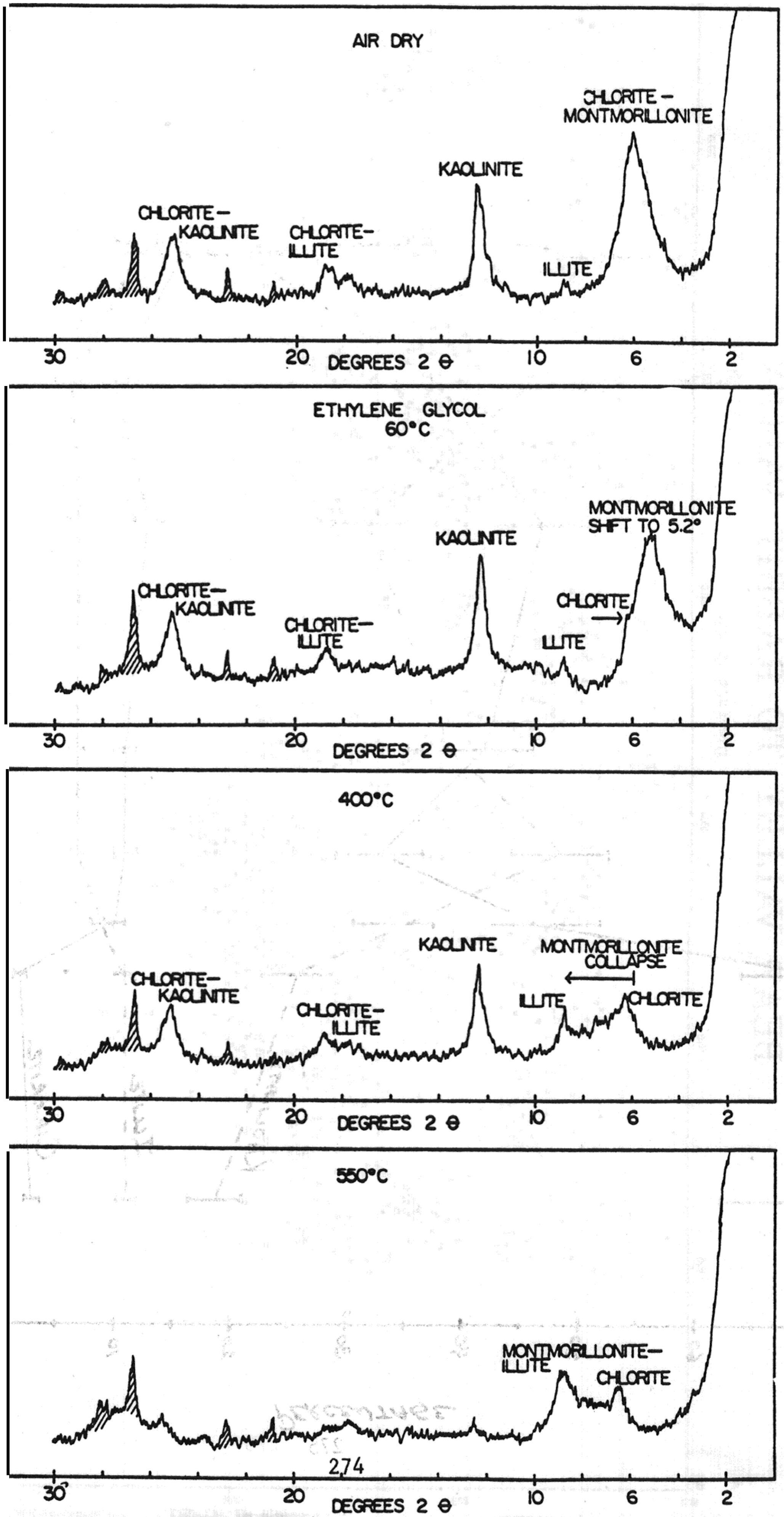
Figure 4: Percentage of clay constituents from various depths in Dry Lake Valley well #1.

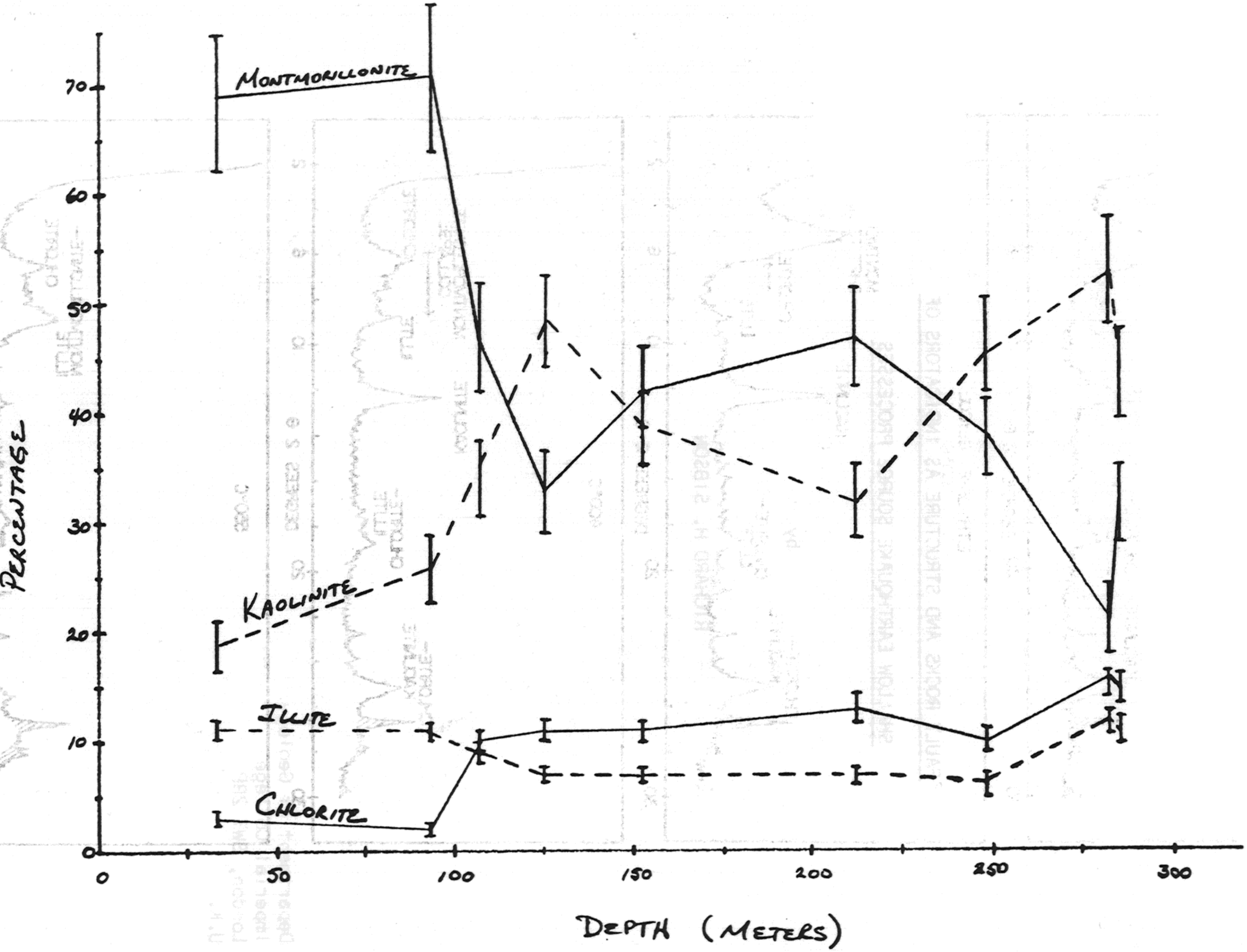

N
0
30 KM.
EXPLANATION
SURFICIAL ROCKS
SEDIMENTARY DEPOSITS
(QUATERNARY)
SEDIMENTARY AND VOLCANIC ROCKS
(TERTIARY TO JURASSIC)
BASEMENT ROCKS
FRANCISCAN FORMATION AND
ULTRABASIC INTRUSIVE ROCKS
(CRETACEOUS AND JURASSIC)
GRANITIC INTRUSIVE AND
METAMORPHIC ROCKS
(CRETACEOUS AND PRE-CRETACEOUS)
A
A'
DRY LAKE VALLEY
DRILLSITE

BEAR VALLEY TO RABBIT VALLEY



DRY LAKE VALLEY # 1
SAMPLE DEPTH 33.5 m





Montmorillonite
Kaolinite
Illite
Chlorite
Percentage
Depth (Meters)
0
10
20
30
40
50
60
70
0
50
100
150
200
250
300