CALIFORNIA WELL SAMPLE REPOSITORY

Supplement to

Special Publication No. 2

Winters Sand Display, May 7-12, 1979

Core Description and Interpretation

Cities Service Co,
Nixon Community No. 1

Solano County, California,
Section 15 T5N R3E

R.W. Tillman,
R.M. Scott & J. Rennison

Cal State
Bakersfield
9001 Stockdale Hwy 93309
(805) 833-2324

CORE DESCRIPTION AND INTERPRETATION,
CITIES SERVICE OIL CO., NIXON COMMUNITY NO. 1,
SOLANO COUNTY, CALIFORNIA, SECTION 15, T5N R3E

R. W. Tillman, R. M. Scott, and J. Rennison

The sandstone in the CSO Nixon Community No. 1 has as its most notable aspect a "massive" unbedded nature. Aligned horizontal shale fragments and mica flakes (especially in the basal 3 ft of the cored interval) suggest that the bedding is horizontal but generally unobservable. A very sharp, non-gradational, upper contact of the sandstone with the overlying shale is observable in the core photographs (Figure 1). The base of the sandstone was not cored; however, the blocky log character of this sandbody (Figures 2 and 3) suggests that the basal contact may be equally sharp and non-gradational.

GEOLOGICAL ANALYSIS AND CORE DESCRIPTION

Sandstone

Sedimentary Structures

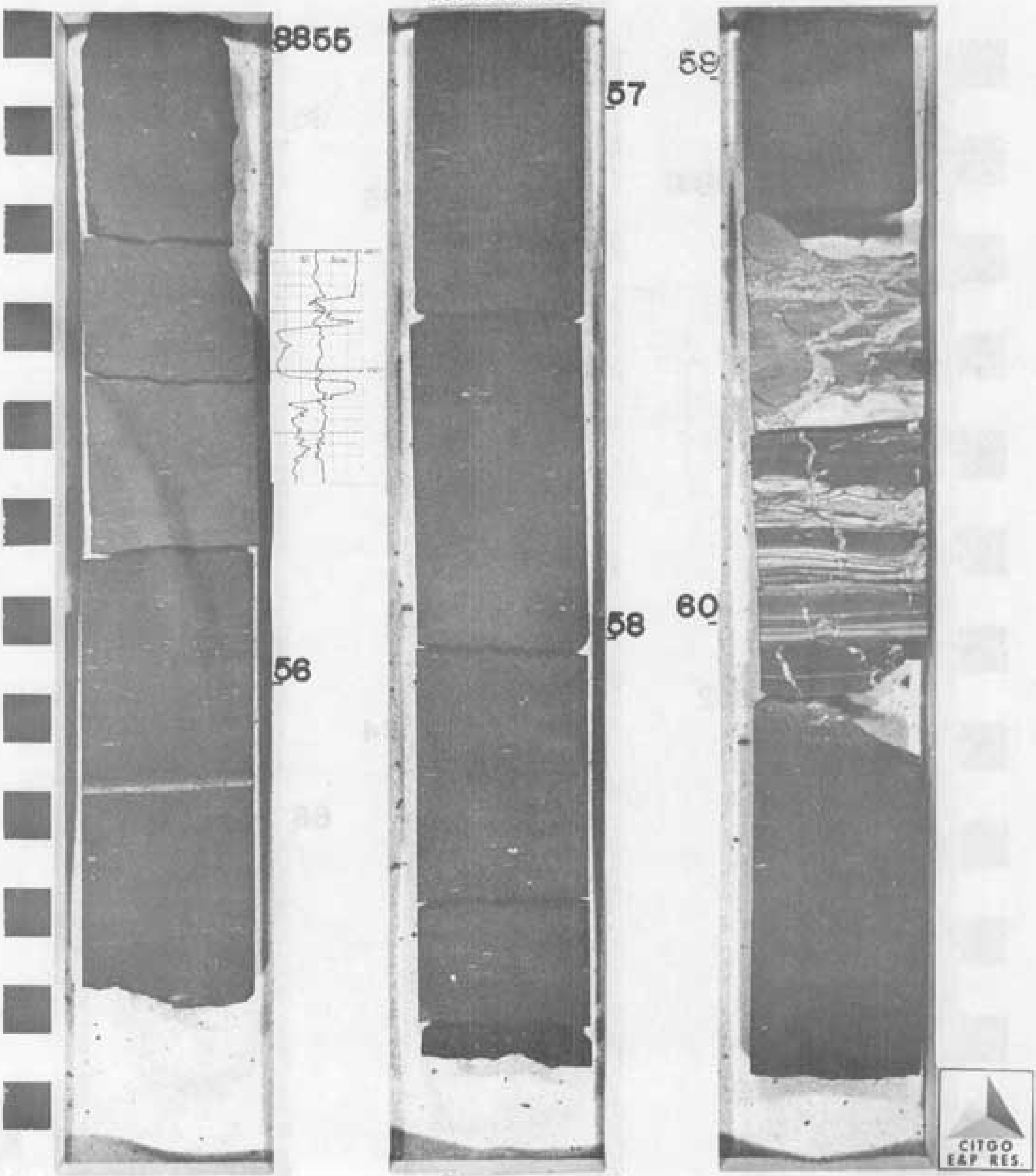
Because the sandstone in this core is predominantly massive-appearing, the entire core was x-rayed, including the shales which overlie the sandstones. X-ray radiography often aids in recognizing sedimentation units through a more exact definition of physical and biogenic sedimentary structures and is, therefore, very useful in reconstructing the depositional history of massive-appearing sandstones. Uniformly-thick (1/2 to 5/8 inch) slabs were cut from the center of the full-diameter core, polished on both sides, and x-rayed. Positive contact prints were then made from the x-ray radiograph negatives.

An examination of x-ray radiographs reveals a predominance of subhorizontal to low-angle (<10°) cross-lamination within the sandstones, although portions of the core are indeed massive (mainly above 8872 ft). Burrows were not observed within the sandstone. Photographs of polished core slabs are paired with contact radiograph prints in Figures 4 and 5 to illustrate the bedding revealed by x-ray radiography.

A thin, distinctly-laminated shale bed is present at 8874 feet, and large shale clasts are present within the sandstones both below this shale bed and at 8876 feet. Similarities between these shale clasts and both the thin shale bed at 8874 feet and the shales which overlie the sandstones (above 8860.4

Figure 1. Core Photographs Core #2
CSO Nixon Community No. 1
Solano County, California

C.S.O.
Nixon Community No. 1
Solano Co, Cal.
Sec.15-5N-3E



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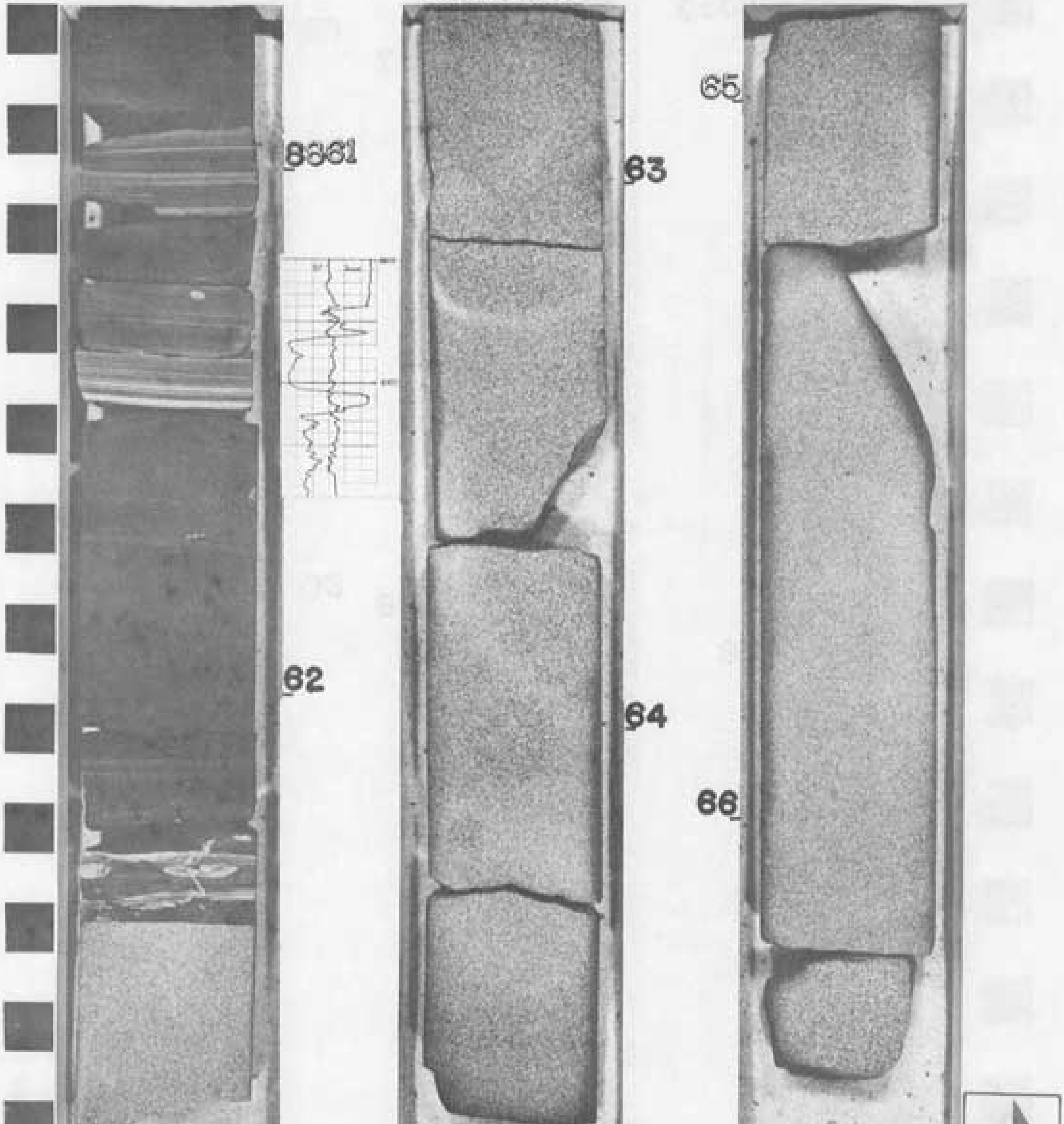
Nixon Community No. 1
Solano Co, Cal.
Sec.15-5N-3E



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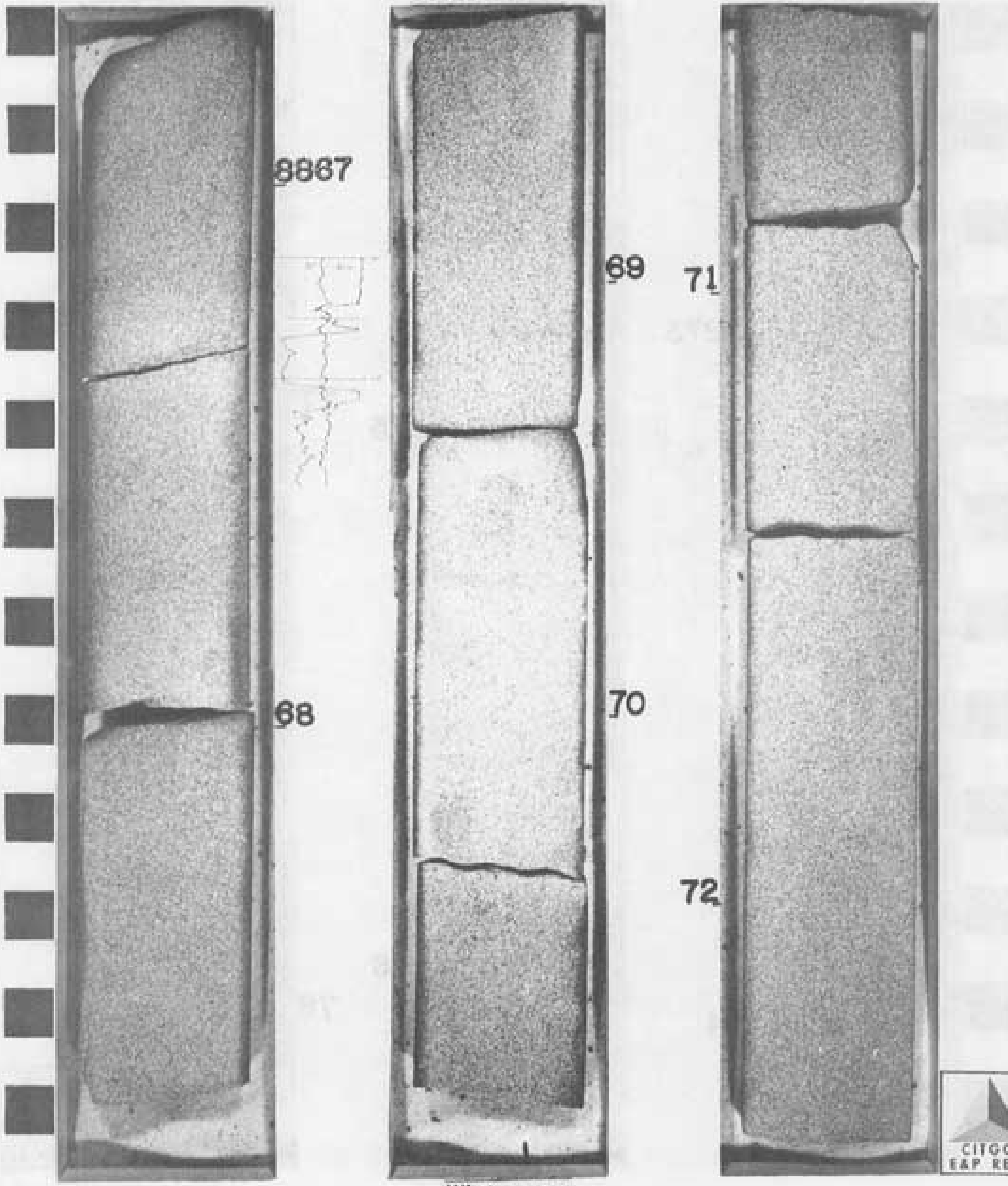
Solano Co, Cal.
Sec.15-5N-3E



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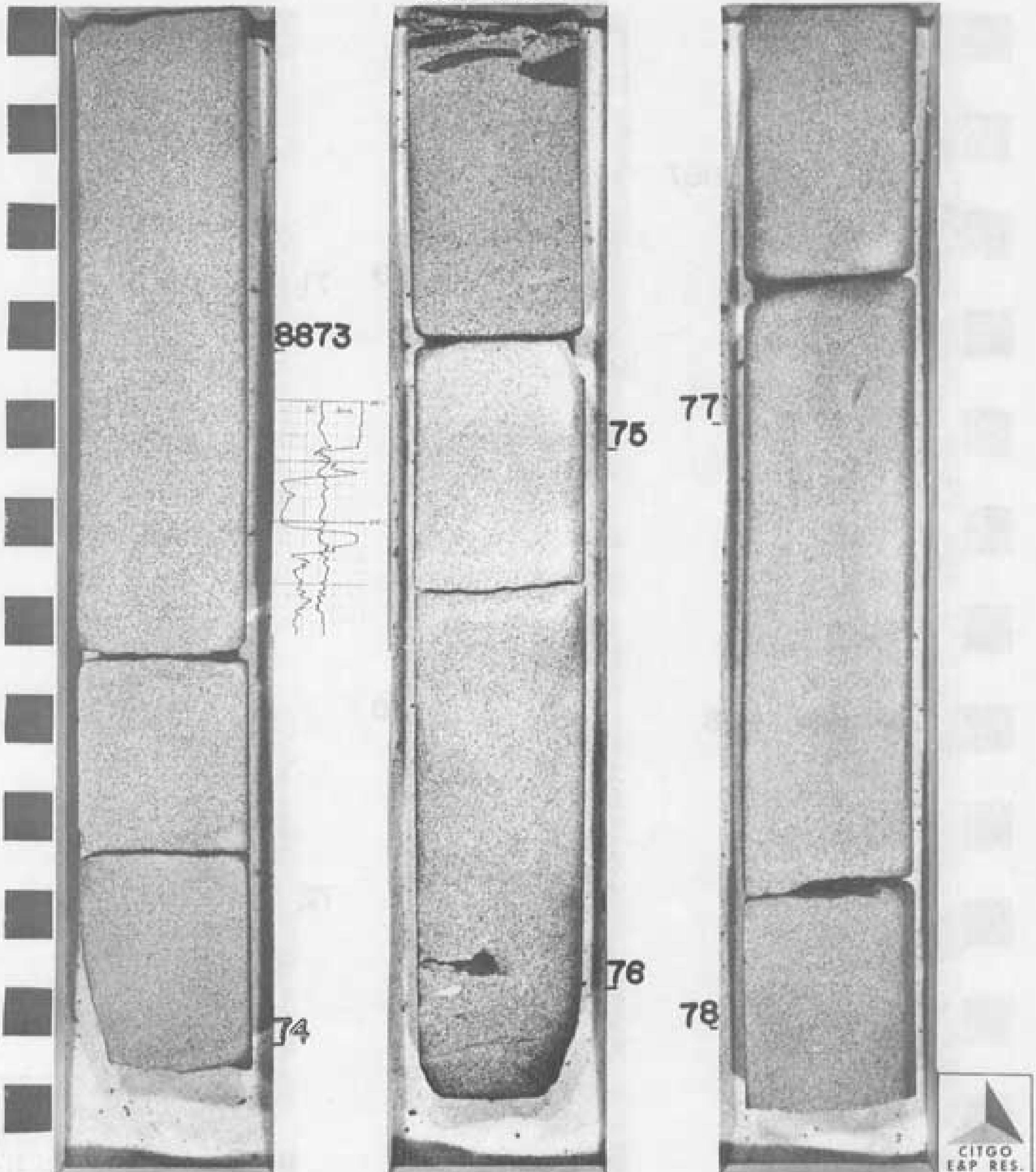
Solano Co Cal.
Sec.15-5N-3E



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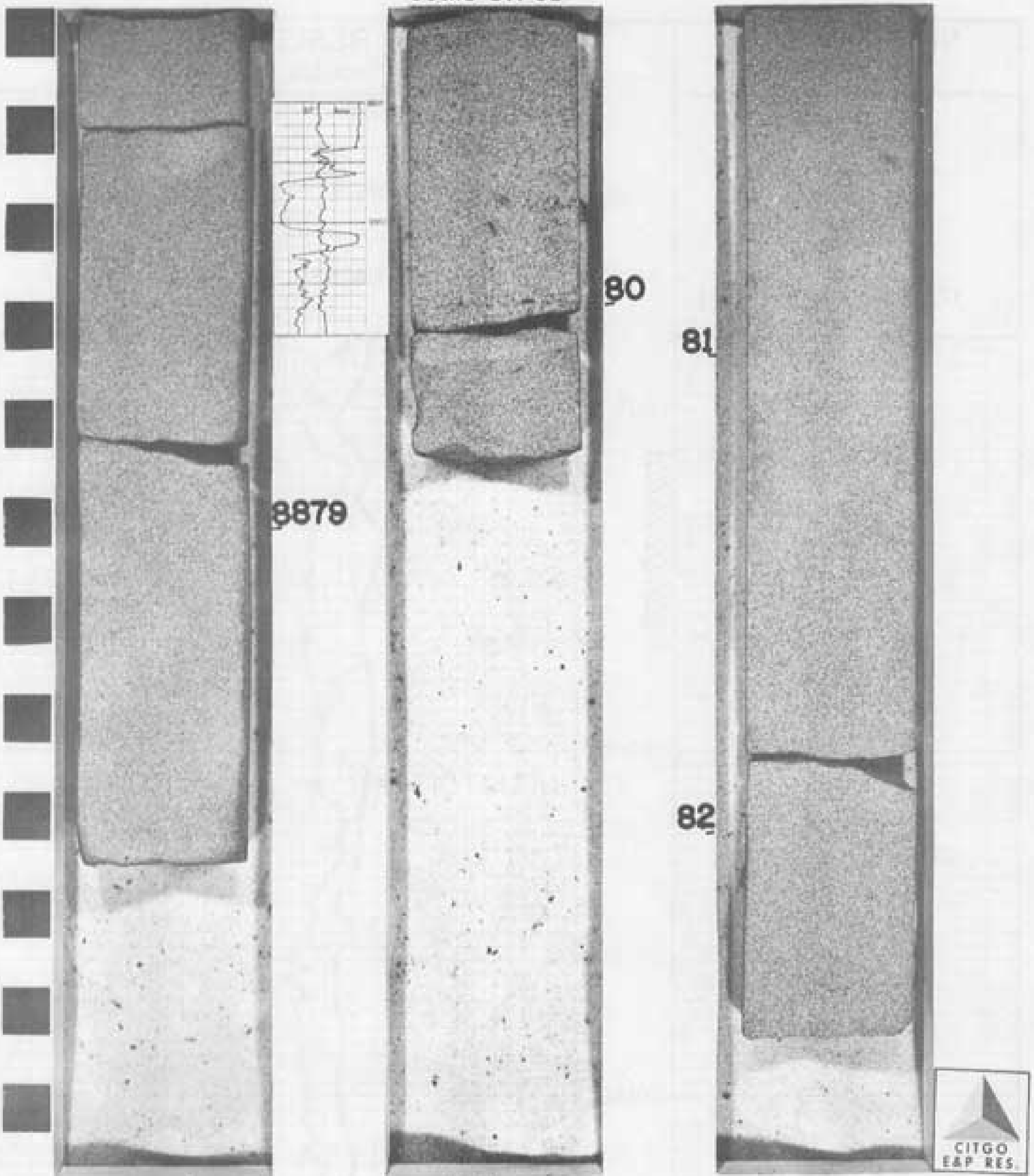
Nixon Community No. 1
Solano Co, Cal.
Sec.15-5N-3E



Winters s.s.

CITIES SERVICE OIL COMPANY
NIXON COMMUNITY NO. 1
NE 1/4 SEC. 15 T·5·N R·3·E RYERS ISLAND FIELD
SOLANO COUNTY, CALIFORNIA

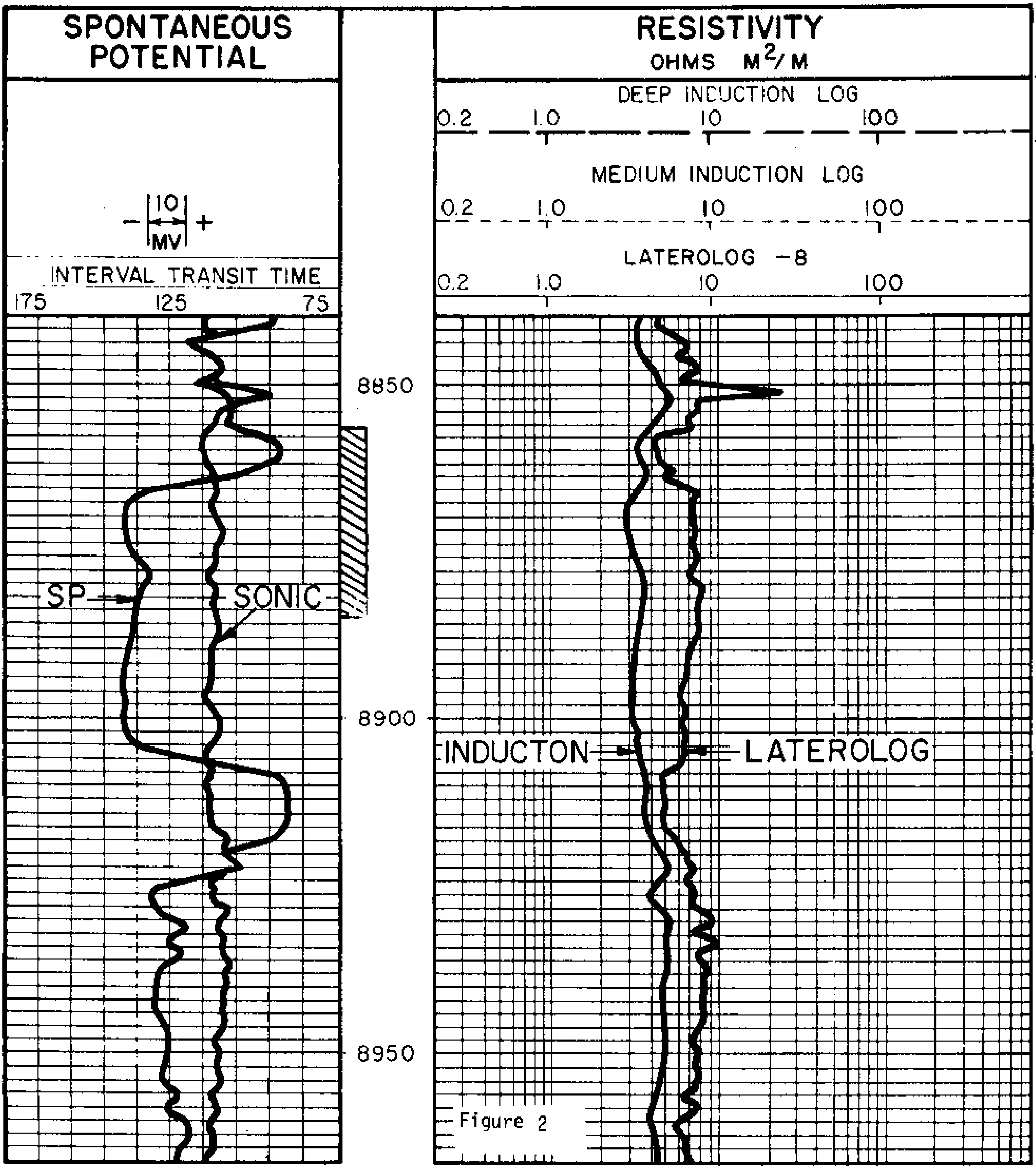


Figure 2

CORE TO SUBSURFACE LOG CORRECTION = 0 TO -3.5' ?
SUBSURFACE LOG TO CORE CORRECTION = 0 TO -3.5'(?)
CORE TO SUBSURFACE GAMMA RAY +1.5

ELEV. KB = 10'

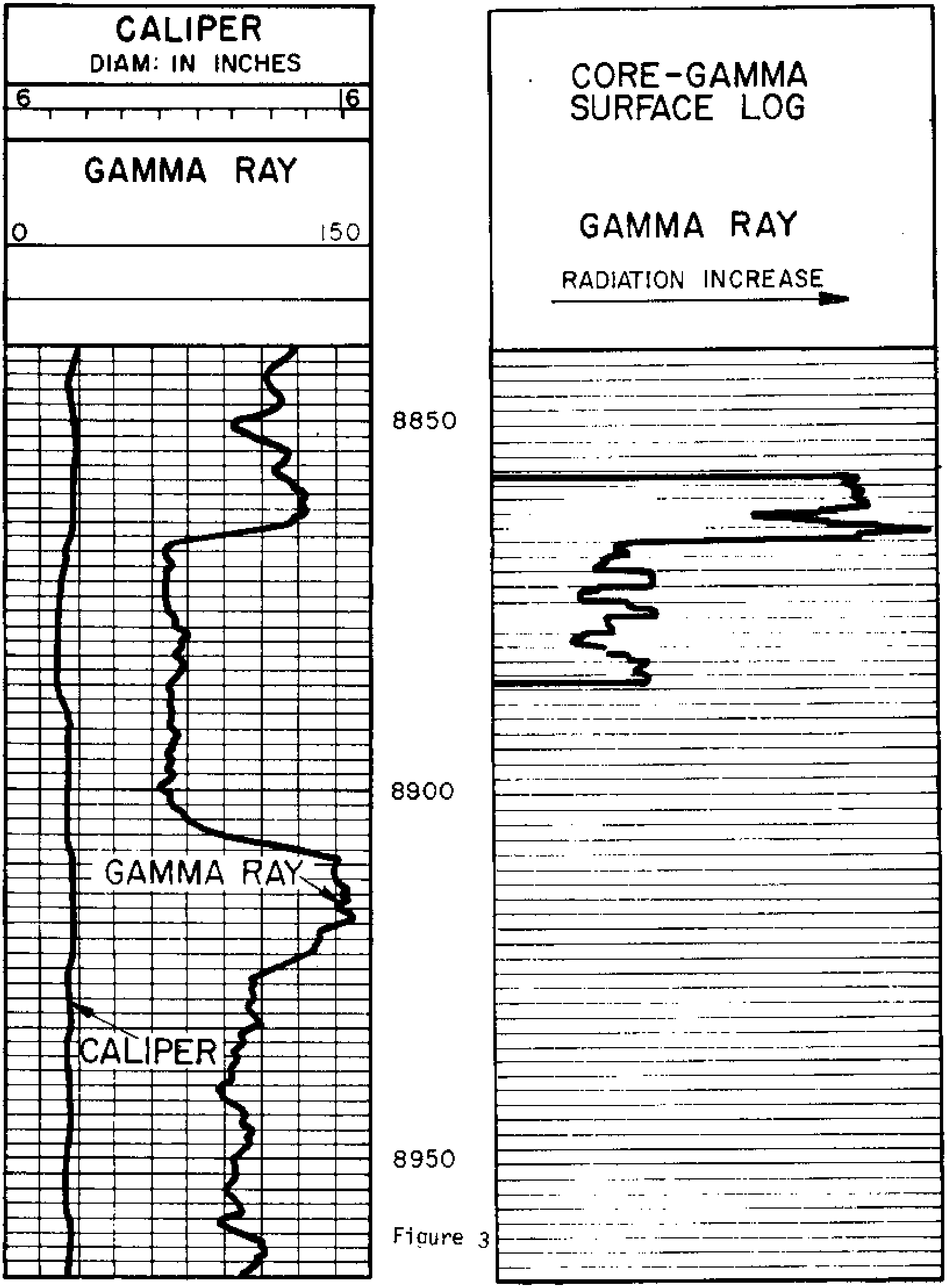
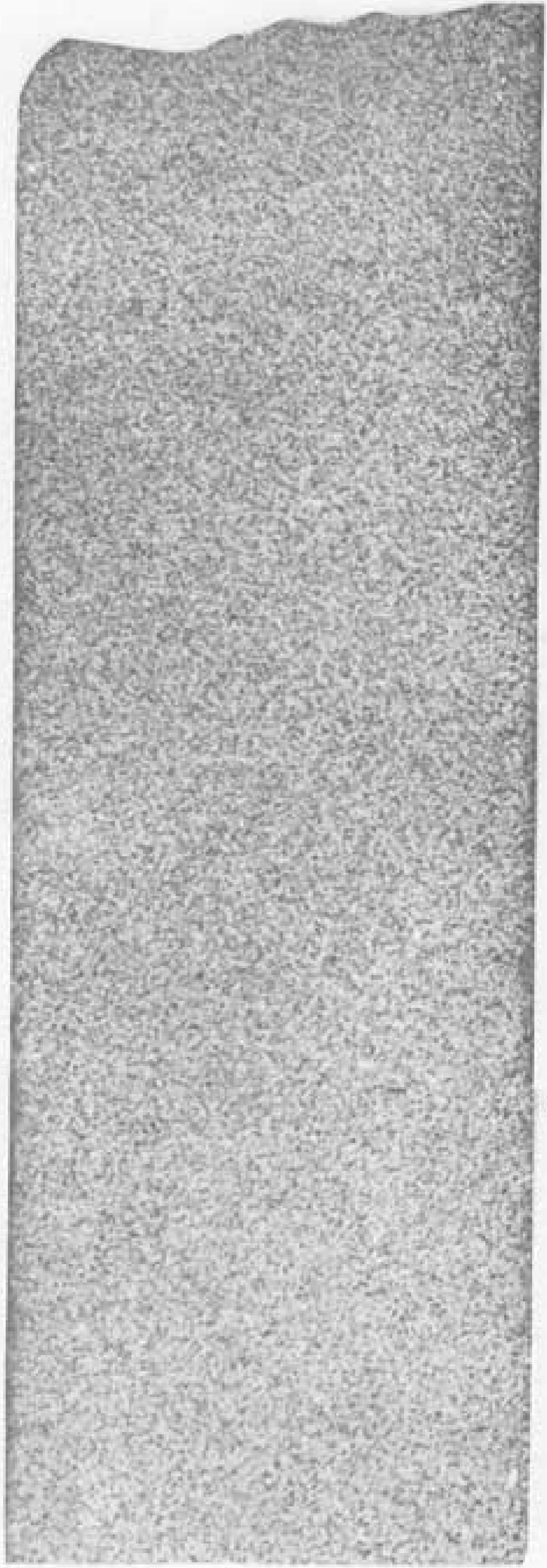


Figure 3

Figure 4. X-ray radiograph print (right) reveals the presence of subtle or diffuse low-angle cross lamination (down to the left) in massive-appearing sandstones; no bedding is visible on the polished surface of the core (left). Lamination appears due to orientation of elongate grains and platy minerals. Core depth is 8873 feet.



8873

1 in.

Figure 5. Bedding is not evident on the polished core surface (left) at 8875 feet, but is fairly well defined by orientation of platy minerals and flattened shale clasts (→) in the x-ray radiograph contact print (right); the large clast was present only in the x-rayed half of the core. Lamination in these sandstones is subhorizontal to slightly inclined (down to the right).

8875

1 in.

feet) suggest that the clasts were derived from within the basin of deposition and are probably rip-up clasts of relatively local origin.

Lithologic Aspects and Petrography

Microscopic examination indicates the presence of abundant clay (8-15% by volume), an abundance of angular to subangular grains, and a conspicuous amount of greenish and gray feldspar and rock fragments. Although there is no obvious grading or textural change, non-systematic changes are recognized within the vertical sandstone sequence based on an evaluation of three parameters: variation in percent clay (8-15%), changes in the sorting of the sand grains, and a variation in the percentage of platey shale and mica grains.

A single thin section from 8879.5 feet was point-counted to obtain data to compare with the petrofacies of Dickinson and Rich (1972) and to evaluate the effects of diagenesis on the sandstone. Results of the point-count are summarized in Table 1. Comparison of these data with the petrofacies was not conclusive.

The thin-section analysis indicates that rock fragments, mainly sialic and mafic volcanics, constitute 26% of the framework fraction. The remaining framework constituents, in order of decreasing abundance, are quartz, orthoclase, plagioclase, biotite, and chert. Authigenic clay, quartz, and feldspar are the dominant cements within the sandstones.

X-ray Diffraction Analysis

The clays in the sandstone in the core range from 8-10% by weight (Table 2). Kaolinite is slightly more abundant than illite and chlorite. Montmorillonite is present but in lesser amounts.

The clays in the shale overlying the sandstone are significantly lower in kaolinite. The kaolinite in the sandstone is apparently diagenetic (as opposed to detrital), resulting from alteration of feldspars. Textures observed in scanning electron microscope photomicrographs strongly suggest that the clay "booklets" in the sandstone grew there. The absence of kaolinite in the shales is due to either the absence of feldspars to be modified to kaolinite or a different geochemical field (i.e., slower ion or fluid movement) such that alteration of the kaolinite did not take place.

TABLE 1

CSO Nixon Community No. 1 - 8879.5'

Petrography by J. Rennison

COMPOSITION SUMMARY

1) Framework Grains = 80%
   a) Altered framework grains (14%).

2) Matrix = 0%.

3) Cement = 10%. (Authigenic clay, quartz, feldspar)

4) Porosity = 10%.

FRAMEWORK COMPOSITION

Quartz 20%

Chert 4%

Biotite 6%

Plagioclase 12%

Orthoclase (K-spar) 12%

Rock fragments 26%

- a) sialic volcanic (12%)
- b) mafic volcanic (12%)
- c) granitic (2%)

COMPOSITION RATIOS

As defined by Dickinson and Rich, 1972

(1) $\frac{\text{Quartz}}{\text{Feldspar}} = \frac{12}{13} = .92$

(2) $\frac{\text{Feldspar}}{\text{Lithic}} = \frac{13}{15} = .86$

(3) $\frac{(1)}{(2)} = Q/F/L = 1.06$

(4) $\frac{\text{Plagioclase}}{\text{Feldspar}} = \frac{6}{12} = 0.5$

(5) $\frac{\text{Volcanic Rock Fragments}}{\text{Lithic Rock Fragments}} = \frac{12}{15} = 0.8$

(6) Mica = 6%

FRAMEWORK FABRIC

1) Elongate grains subparallel to laminae.

2) Grain contacts mainly point contact.

3) Sorting is poor (1.3) throughout. (Based on 5 samples)

TYPES AND HOSTS OF ALTERATION PRODUCTS

Host	Alteration Production
Biotite	Pyrite and chlorite
Granite fragment	Chlorite (this is unusual)
Mafic volcanic fragment	Chlorite
Sialic volcanic fragment	Albite and chert
Orthoclase	Kaolinite

PARAGENETIC (ALTERATION SEQUENCE)

1) Initial alteration of most unstable volcanic rock fragments.

2) Clay rims on framework grains.

3) Development of quartz overgrowths.

4) Alteration of K-spar to kaolinite.

5) Growth of authigenic K-spar into pores, locally growing over kaolinite.

NOTE: Diagenesis is relatively mild compared to other Great Valley Sequence rocks. The percentage of montmorillonite (Table 2) is anomalous considering the abundance of volcanic material.

TABLE 2

Semiquantitative Percent Analysis of
Less Than 5 Micron Size Fraction

Sample Depth	Lithology	%<5μ	Mont-moril-onite	Illite	Chlorite	Kaolinite
8861.5'	Silty laminated shale	23.4	12	14	18	7
8862.5'	Sandstone	10.1	3	11	9	16
8866.8'	Sandstone	9.3	2	9	7	13
8869.5'	Sandstone	7.5	2	6	5	11
8875.0'	Sandstone	7.8	2	7	5	11
8879.5'	Sandstone	7.9	4	9	8	12
8882.5'	Sandstone	10.1	4	9	9	12

TABLE 3

Sequential Grain Size Data
CSO Nixon Community No. 1, Solano Co., California

	Subsurface Depth	Mean Size ϕ	Sorting	Skewness	1% Phi Size	% Silt + Clay	Angle Between Populations A and C*	% Population A Material
Unit 2	8862.5	3.48	1.19	1.50	2.01	23.20	130°	52
	8866.5	2.81	1.36	1.42	.83	16.16	138°	60
	8869.5	2.74	1.31	1.46	.71	14.18	142°	72
Unit 1	8875.0	2.80	1.34	1.33	.74	16.04	143°	66
	8879.5	3.17	1.32	1.25	1.16	20.76	143°	66
	8882.5	3.44	1.35	1.12	1.49	26.30	146°	55

* For definition of A and C Populations, see Moss (1962) or Tillman and Reineck (1975).

Shale

The shale which overlies the sandstone is horizontally bedded for the most part, but does contain silty and sandy zones which are horizontally bedded or contorted or obliquely to horizontally burrowed. Fossil shell debris is abundant and a pelecypod fragment was observed at 8855.3 feet. None of the features observed in the shale are alien to turbidite deposition, and this general association would be expected in turbidite deposits. The shales above 8859.5 feet definitely were deposited in an area below wave base and in an area where bottom currents were absent. Most of the shale is deposited in horizontal laminae presumably from suspension and few, if any, micro-scale ripples are present in the shale. The shale yielded a dominantly to wholly agglutinated microfaunal assemblage suggestive of slope depths and was deposited during the E foraminiferal zone of Goudkoff (1945), (Dailey, personal communication). The shales interbedded with the sandstones were barren.

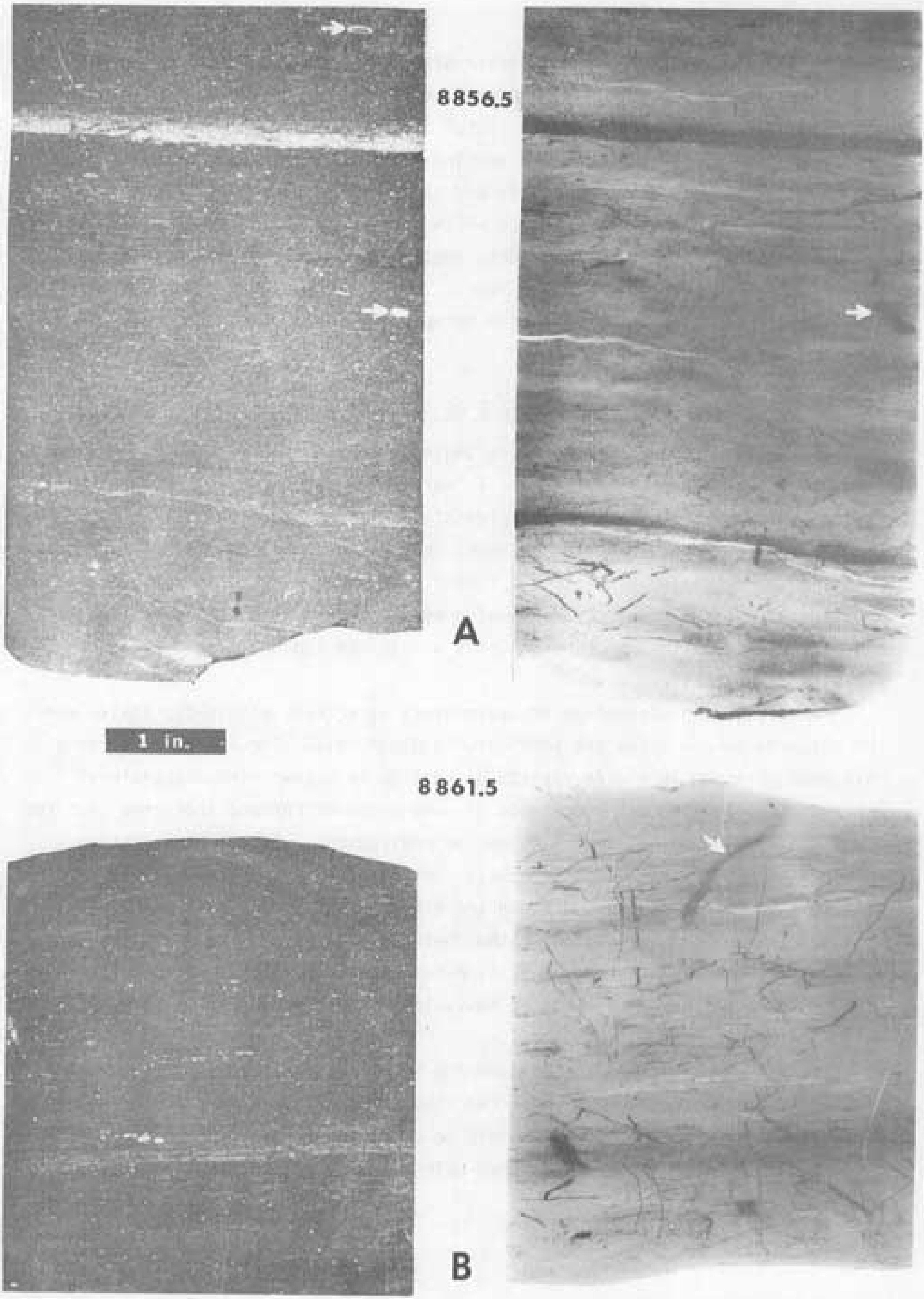
Burrowing and Bioturbation

Examination of the polished core surface indicates that three types of burrows are prominent in the shales. The most conspicuous burrow is the white, silt-rimmed, slightly flattened 1/16-1/8 inch diameter burrow present in trace amounts in the shales from 8856.2-8859.4 feet. Oblique 1/4 inch diameter burrows are observed in two shale zones, one from 8859.5-8860.2 feet and a thin zone just above the sandstone (8862.0-8862.2 feet). In this upper zone, the white mud, sand and silt-filled burrows are associated with sandy and silty horizontal beds and convoluted and deformed rippled pods of sandstone and silt. The most intense burrowing is in the shales in the zone from 8862.0-8862.2 feet where 1/32 inch diameter horizontal burrows occupy 80% of the shale. X-ray radiography reveals that similar small diameter (1/32-1/64 inch) sinuous burrows (oblique to subhorizontally oriented) are actually abundant throughout the shales (Figure 6) but are discernible on the polished surface only when highly concentracted.

GENETIC UNITS

The SP and gamma ray logs show a blocky character (Figures 2 and 3) in both the subsurface logs and the surface gamma ray log. Superficially, on the basis of log data, the sandstone might be considered to be a single genetic unit; however, two lines of evidence suggest that it is composed of at least two genetic units.

Figure 6. Photograph of polished core slab (left) paired with the positive contact x-ray radiograph print (right) of the same core interval. A) Two burrow types present in shales at 8856.5 feet include 1/16-1/18 inch diameter silt-lined burrows (→) and small diameter (1/16-1/64 inch) sinuous oblique to subhorizontally oriented burrows. Two thin subhorizontal siltstone beds are present and appear black on the x-ray print. B) More densely burrowed shales at 8861.5 feet have three types of burrows of which the small diameter sinuous burrows are most abundant. Silt-lined burrows are again present along with a sinuous oblique-oriented 1/8 inch diameter burrow (→); both occur in trace amounts. Subhorizontal dark bands on the x-ray print are siltier beds.


8856.5
A
1 in.
8861.5
B

Two vertical sequences of grain-size data, designated units 1 and 2, are listed in Table 3. Both sequences have decreasing mean grain sizes upward. The changes in the other variables listed in the table follow the same vertically changing sequence. Only the sorting remains relatively constant throughout both units. The sorting is poor and varies only between 1.19-1.36.

The second piece of evidence which confirms the differentiation into the two units based on the grain-size date sequences is the presence of a thin (0.5 inch), well-bedded shale at 9974.0 feet. This shale was deposited by low energy processes, presumably during a hiatus between the major flows which deposited the sandstone units 1 and 2.

ENVIRONMENTS OF DEPOSITION

The environment of deposition suggested for the cored sandstone (8862.5-8882.4 feet, core depths) is that of a "turbidite" deposited in a deep-water basinal setting. The general characteristics of this sandstone differ from those ascribed to the Bouma Sequence. Rather, they appear analogous to B-facies sandstones described by Mutti and Ricci Lucchi (1975). The predominance of subhorizontal and low-angle cross bedding, as revealed by x-ray radiography, and vertical stacking (amalgamation) of genetic units within the sandbody are typical of B-facies sandstones.

Neither the assemblage of sedimentary structures within the shales nor the observed burrow types are particularly diagnostic. These characteristics have been observed in a wide variety of shallow to deep-marine depositional environments. However, the presence of deep-water microfauna indicates that the shale was also deposited in the submarine environment. This interpretation explains the very sharp sandstone-shale contacts observed in the core which suggest that sandstone deposition began and ended abruptly. Shales were deposited by accumulation from suspension, either between periods of sand deposition, or in association with sand deposition as fine-tail turbidity deposits, or both. Within this context, these shales would be equivalent to either the G facies or D facies described by Mutti and Ricci Lucchi.

From the work done in the Apennine Mountains in Italy by Mutti and Ricci Lucchi (1972, 1975), it can be inferred that the sandstones in this core were deposited either in middle fan channels or outer fan lobes. This is suggested by the association of B facies sandstones with D facies and/or G facies shales.

down the paleoslope during Winters time. If the sandstones are part of a lobe, they may be part of a generally eliptically-shaped sandbody elongate downslope.

RESERVOIR CHARACTERISTICS

The Winters sandstones are characterized by high porosities, generally within the range of 20-30%, and permeabilities ranging between 150-950 md. Thus, reservoir parameters for these sandstones are excellent. Porosity and permeability data obtained from analysis of Winters sandstones in the Nixon Community No. 1 core are compiled in Table 4 along with grain density and bulk density determinations. Additionally, a compilation of observations made during this core analysis is presented in Table 5.

ACKNOWLEDGEMENTS

Our thanks to Cities Service for permission to reproduce this material. Bill Almon provided interpretations of x-ray diffraction data. The micropaleontological analysis and interpretations were contributed by Don Dailey, and Bill Pusch provided porosity and permeability data. Rex Young recommended that the core study by initiated. Core photography and darkroom expertise were contributed by Fred Mason and Chris Berlin.

TABLE 4

CSO NIXON COMMUNITY #1
SOLANO COUNTY, CALIFORNIA
TEST DATA

Depth ft	Permeability md	Porosity %	Grain Density	Bulk Density
8862.5	311	25.95	2.66	1.97
8862.6	540	26.79	2.65	1.94
8864.0	770	25.79	2.63	1.95
8864.1	840	26.33	2.64	1.95
8866.8	890	26.52	2.63	1.93
8866.9	970	27.38	2.65	1.92
8869.5	720	25.11	2.63	1.97
8869.6	850	25.68	2.64	1.96
8873.8	440	25.14	2.65	1.98
8873.9	Broken	24.34	2.65	2.00
8874.5	145	23.58	2.66	2.03
8874.6	173	23.84	2.65	2.02
8875.0	435	24.63	2.63	1.98
8875.1	485	25.26	2.64	1.97
8878.0	250	24.61	2.65	2.00
8878.1	238	24.20	2.65	2.01
8879.5	191	23.99	2.64	2.01
8879.6	218	24.30	2.65	2.01
8882.3	146	23.74	2.65	2.02
8882.2	144	24.31	2.66	2.02

TABLE 5

DETAILED SUMMARY

Cored Interval: 8855'-82.4' (27.4')

Log to Core Correlations:

Top of Sandstone: Core - 8862.5' Gamma Ray Log (Core) 8864.0'

SP - Resistivity Log - 8866.0'

Corrections:

Core to subsurface log +3.5'
Subsurface log to core -3.5'
Core to GR (core) log +1.5'
GR (core log) to core -1.5'

General Comments (Sandstones):

Mineralogy - abundant green grains presumably basalt or graywacke grains. Quartz 20-40%

Contacts - Very sharp upper contact; sandstone overlain by shale. Lower contact of sandstone not cored.

Features within sandstone -

1. Total absence of bedding. "Massive." Probably horizontally laminated.
2. 8874.4' - 3" zone of edgewise conglomerate. Clasts are silty shale with 1/64" diameter burrows (horiz.); black burrows in gray shale. One clast has distorted lamina 1/64" x 1/4" long.
3. 8876' - irregular shaped 3/4 x 1" sandy shale inclusion. Contains 10% sand grains not point contact (floating in shale).
4. High % of authigenic (and detrital?) clay in sandstone; varies vertically from 8-15%. Kaolinite with co-equal amounts of chlorite and illite. Trace of montmorillonite (Table 2).
5. 1/32" x 1/8" long horizontally oriented flakes of shale and/or mica. Amount varies vertically, most abundant near base of core below 8874'.
6. Grains very angular, less than 30% of the grains are rounded in much of the sandstone.

Environment of deposition interpretation: B Sandstone (Mutti); Turbidite.

General Comments (Shale):

1. Horizontally laminated with no ripples except where silty or sandy. Not fissle. Ripples maximum 1/4" high.
2. 8856.2' - Poorly sorted sandy horizontal lamina with sharp top.
3. Silt rimmed (squashed) burrows, 1/32" high 1/8-1/2" long in interval 8856.2 - 59.4', maximum 1% (by volume). Burrowing 5-20% (max) in core in general. Mostly very small 1/64" or less. Trace of silt rimmed burrows at 8861.5'
4. 8855.3' - Partitioned shell (marine fossil), pelecepod?
5. 8859.5'-60.0' Vertical burrows cutting through sandy ripples (deformed) in shale. Some 1/4" or less thick horizontal beds of silty sandstone. 1/4" diameter oblique sand filled burrows.
6. 8862.2' - 1/2" diameter burrow; filled with sand and small deformed shale clasts.
7. 8862.3-62.4' - Deformed, rippled(?) and convolute(?) silty sandstone in shale. A few 1/8" diameter oblique burrows. Sharp lower contact with sandstone. 80% shale. 1/32" diameter horizontal burrows.

Environment of Deposition Interpretation: Subtidal Marine to deep Marine (100%)
Slope (70%)

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