BMR RECORD 1978/37

PETROLEUM SOURCE ROCK POTENTIAL FROM WIRE-LINE LOGS

by

L.E. KURYLOWICZ

CONTENTS

FIGURES

SUMMARY

Quantitative petroleum source rock detection up until now has depended upon detailed laboratory analysis. The possibility of using wireline logs to replace or aid part of the laboratory techniques has been investigated.

Plots of log conductivity, log sonic interval transit time, density, and log neutron porosity were all plotted against depth. Departures from 'normal' on these plots indicate either high total organic carbon (TOC) content or overpressuring of the formation. If pressure data are available these two possibilities can be distinguished. In either case, the departures on the plots indicate depths of probable hydrocarbon occurrences.

The log values may also be plotted against one another, but these cross-plots, though showing some signs of being useful, have not yet been fully evaluated. A joint study with the Petroleum Technology Laboratory is recommended to do this.

INTRODUCTION

The possibility of using wire-line logs to distinguish petroleum source rocks from 'barren' rocks is the ultimate goal of this investigation. Details of present uses of wire-line logs in source rock potential studies are also given.

THEORETICAL CONSIDERATIONS

Origin of petroleum

Hood & others (1975) consider that the origin of petroleum can be described generally by four successive stages:

(1) the formation of organic-rich, fine-grained sediments through the photosynthesis, deposition, and preservation of abundant organic matter;

(2) the thermal degradation of that organic matter during burial, forming petroleum molecules;

(3) the expulsion of oil and gas from its fine-grained source rock, and its migration through and entrapment in porous, permeable, reservoir rock; and

(4) the physical, thermal, and/or biological alteration of petroleum in reservoir rock.

Present methods of recognising source rocks

McKirdy and Horvath (1976) list four criteria for distinguishing a source rock from a 'barren' rock. The first two are:

(1) the rock must contain sufficient organic matter to have generated a significant amount of oil. They state that total organic carbon (TOC) in shales needs to be at least 0.5% to have generated commercially significant quantities of petroleum. The other laboratory derived parameters of extractable organic matter (EOM) and composition of EOM are not pursued in this article;

(2) the rock must have been subjected to temperatures and pressures high enough to convert the organic matter to oil.

Overpressured formations

The control of overpressured formations (formations with abnormally high fluid pressure) has been of major importance in the design of drilling programmes for petroleum wells. The presence and intensity of such zones affect both the design and choice of mud system. Methods of predicting overpressured (geopressured) formations are outlined by Jorden and Shirley (1966) and by Eaton (1976).

A theory advanced to explain abnormally high fluid pressures is put forward by Powers (1967). He states that these pressures (overpressures) may easily be caused by a volume increase associated with the desorption of the last few monomolecular layers of water from montmorillonite during its diagenesis to illite. Thus a mechanism whereby generated hydrocarbons may be moved out of the 'source' rock into adjacent reservoirs is documented.

Burst (1969) also studied the diagenesis of clay and its possible relation to petroleum migration. He outlined three dehydration stages:

(1) Pore water and excessive (more than two) clay-water interlayers are removed by the action of overburden pressure. This initial dehydration (the first few thousand feet of burial) reduces the water content of the sediment to about 30 percent;

(2) The second stage of dehydration is achieved when the penultimate water layer is removed (at about 220°F). The amount of water moved is 10-15 percent of the compacted bulk volume and represents a significant fluid displacement capable of redistributing any oil or gas formed;

(3) The third stage occurs at very deep depths at which there is little or no permeability and requires a long time (tens to hundreds of millions of years).

Burst's study (1969) showed that the second dehydration stage may occur within the depth range of 4000 - 16000 ft. He notes that a significant correlation exists between this dehydration level and the occurrence of petroleum in the Gulf Coast area of America.

WIRE-LINE LOGS

Wire-line logs were initially designed and used by petrophysicists to evaluate reservoir rock properties with little emphasis on shale sections. The safety aspects and economic gains of early detection of overpressured zones was the turning point in shale evaluations.

The present ability to differentiate 'reservoir' lithologies by cross-plotting techniques (Burke & others, 1969) may possibly be extended to fine-grained sized rock (or source rock). Brief descriptions of presently used log interpretation techniques in the source rock area are given below.

Temperature log

Maximum bottom hole temperatures (BHT) are normally recorded on all well logging operations. However the downhole temperatures recorded during routine logging operations do not measure true, static formation temperature. Owing to the cooling effect of circulating drilling mud, used to condition the hole before logging operations, recorded temperatures can be 25-70°F lower than true, static formation temperatures (Fertl & Wichmann, 1977). Edwardson & others (1962) mathematically treated the temperature correction (true static formation temperature) analogously to pressure-build up methods and presented their solution in a series of graphs.

Thus, if present day static formation temperatures are accepted as indicative of minimum palaeotemperatures operative in post-organic time, the chart in Bostick (1973, fig. 5) can be used to determine the level of organic maturity in relation to burial time.

Electric log

Induction logging devices were designed to measure deep investigation formation resistivity and are focussed devices in order to minimize borehole effects. In normal pressured shales, with the induction-log plot, there is a decrease of conductivity with depth. Matthews & Kelly (1967) found that a linear correlation exists when depth is plotted against the logarithm of shale conductivity. The standard log presentation of conductivity is a linear scale from zero on the right to 500 millimhos/m on the left. Schlumberger (1972) arbitrarily scale conductivity as 1000 divided by resistivity value in ohms-m^2/m. Shale-reading points that fall to the left of the normal line are zones of subnormal pressure and points to the right of the normal line are zones of abnormally high pressure.

Sonic log

The sonic log is a recording, against depth, of the time required for a compressional sound wave to traverse one vertical foot of formation. In normal-pressure shales, the sonic log shows a decrease in interval transit time with depth. This is similar to the conductivity-depth plot. Since interval transit time is a function of porosity, this decrease shows that shale porosity decreases with depth (Matthews & Kelly, 1967).

Other porosity logs

The density log is a continuous record of variations in the density of the lithologic column cut by the borehole. The term 'bulk density' is applied to the overall or gross density of a unit volume of rock.

The neutron log is often a standard counterpart of the gamma ray log. This combination provides information as to the lithology and the porosity of the formations. Neutron logs respond to the fundamental formation property of hydrogen richness (Dresser Atlas, 1974). If all of the formation's hydrogen is contained in the form of liquid, and if these liquids completely occupy the total pore volume, hydrogen concentration is an index of porosity.

Thus intuitively, plots of shale density and shale neutron porosity against depth should decrease with depth. Abnormal high departures from a normal gradient should also indicate abnormal high pressured zones.

EXPERIMENTAL TREATMENT OF LOG DATA

Three wells which had readily obtainable TOC values and logs were chosen - Palm Valley No. 1, East Mereenie No. 1 and Ashmore Reef No. 1. Where available, conductivity, sonic travel time, density, and neutron porosity were plotted against depth. Then cross-plots of log sonic travel time against log conductivity, density against conductivity, log shale travel time against gamma ray, and neutron against density were attempted. The TOC values used (Kurylowicz & others 1976) are shown in Table 1. Tables 2-4 list the shale log values of the three wells.

The theoretical importance of overpressured zones as indicative of areas where hydrocarbons (if generated) may have migrated from, prompted the application of plots versus depth and cross-plots to Pelican No. 1. In addition, stratigraphic application was attempted in Rob Roy No. 1 and Sahul Shoals No. 1 (see Tables 5-7 for input data).

To facilitate the testing of any correlations between source rock 'quality' as determined by laboratory total organic carbon (TOC) measurements and log measurements a computer plot program (SRPL) was written (Appendix 1).

CONCLUSIONS AND RECOMMENDATIONS

Relatively high values of total organic carbon (TOC) are expressed by departures to the right for plots of logarithm of conductivity and logarithm of shale sonic travel time against depth (Figs 1 and 2) for Palm Valley No. 1, East Mereenie No. 1 (Figs 3 and 4), whereas only the logarithm conductivity against depth plot in Ashmore Reef No. 1 showed a deflection corresponding to high values of TOC (Fig. 5). The logarithmic departure is similar to that caused by overpressuring. Thus with the aid of reservoir pressure data, "apparent overpressuring" is correlated with high TOC values. The detection of real overpressured zones as indicative of areas of petroleum migration is also a positive criteria in source rock evaluation.

Cross-plots of logarithm of shale sonic travel time against gamma ray for Palm Valley No. 1 (Fig. 6) for East Mereenie No. 1 (Fig. 7) and for Ashmore Reef No. 1 (Fig. 8) showed some tendency for high TOC values to plot in the lower left quadrant. However cross-plots of logarithm of shale sonic travel time against logarithm of conductivity (Figs 9-11) were not as definitive. Unfortunately no neutron-density cross-plot data and equivalent TOC values were available for correlation.

Log values from Pelican No. 1 were cross-plotted (Figs 12-15) in order to examine the correlation with known overpressured zones (as measured by formation interval tester). All logs against depth showed a good correlation with the top of an overpressure zone at about 2700 m.

Stratigraphic application, in the identification of erosional unconformities and in some cases in estimating amounts of erosion, is shown for Rob Roy No. 1 and Sahul Shoals No. 1 (Figs 16-19).

It is recommended that a further study on source rock detection by wire-line logs should be conducted jointly with the Petroleum Technology Laboratory. Wells with full suites of logs and ample cores should be studied to enable statistical treatment of the correlations. The project should determine if quantitative source rock data can be obtained from logs or if a semi-quantitative source rock quality scale can be established. A study period of at least six months would probably be needed.

REFERENCES

BOSTICK, N.H., 1973 - Time as a factor in thermal metamorphism of phytoclasts (coaly particles): 7th Cong. Internat. Stratigraphic et Geologie Carbonifere, Krefeld, 1971 Compte Rendu (2), 183-93.

BURKE, J.A., SCHMIDT, A.W., and CAMPBELL, R.L., 1969 - The litho-porosity cross plot. The Log Analyst, 10(6), 25-43.

BURST, J.F., 1969 - Diagenesis of Gulf coast clayey sediments and its possible relation to petroleum migration. Bull. Amer. Assoc. Petrol. Geol. 53 (1), 73-93.

DRESSER ATLAS, 1974 - LOG REVIEW 1. Dresser Atlas Division, Dresser Industries Inc., Houston.

EATON, B.A., 1976 - Graphical method predicts geopressures worldwide. World Oil, May, 51-56.

EDWARDSON, M.J., GIRNER, H.M., PARKISON, H.R., WILLIAMS, C.D., and MATTHEWS, C.S., 1962 - Calculation of formation temperature disturbances caused by mud circulation. Journ. Pet. Tech., April, 416-26.

FERTL, W.H., and WICHMANN, P.A., 1977 - How to determine static BHT from well log data. World Oil, Jan, 105-6.

HOOD, A., GUTJAHR, C.C.M., and HEACOCK, R.L., 1975 - Organic metamorphism and the generation of petroleum. Bull. Amer. Assoc. Petrol. Geol. 59 (6), 986-96.

JORDEN, J.R., and SHIRLEY, O.J., 1966 - Application of drilling performance data on overpressure detection. Journ. Pet. Tech. Nov., 1387-94.

KURYLOWICZ, L.E., OZIMIC, S., McKIRDY, D.M., KANTSLER, A.J., and COOK, A.C., 1976 - Reservoir and source rock potential of the Larapinta Group, Amadeus Basin, central Australia. APEA J., 49-65.

MATTHEWS, W.R. and KELLY, J., 1967 - How to predict formation pressure and fracture gradient from electric and sonic logs. Journ. Oil and Gas, 65(8), 92-106.

McKIRDY, D.M., and HORVATH, Z., 1976 - An integrated scheme for the laboratory analysis of oil, natural gas, and petroleum source-rocks. Bur. Miner. Resour. Aust. Rep. 197.

POWERS, M.C., 1967 - Fluid-release mechanisms in compacting marine mudrocks and their importance in oil exploration. Bull. Amer. Assoc. Petrol. Geol. 51(7), 1240-54.

SCHLUMBERGER, 1972 - LOG INTERPRETATION, VOL. 1 - PRINCIPLES. Schlumberger, New York.

Table 1. Total organic carbon values for Palm Valley No. 1, East Mereenie No. 1 and Ashmore Reef No. 1.

Well Name	Depth m BRT	Depth ft BRT	TOC (weight % of total rock)
Palm Valley No. 1	1407.3	4617	0.26
	1507.5	4945	0.31
	1673.5	5490	0.29
	1716.9	5633	0.67
	1746.8	5731	0.47
	1880.0	6168	0.36
	1972.7	6472	0.29
East Mereenie No. 1	820.8	2693	0.25
	958.3	3144	0.21
	1054.0	3458	1.63
	1056.4	3466	1.81
	1058.0	3471	0.71
	1160.4	3807	0.28
Ashmore Reef No. 1	1989.7	6528	0.03
	2065.3	6776	0.18
	2211.3	7255	0.14
	2221.7	7289	0.008
	2443.9	8018	0.49

(Analysis carried out by Z. Horvath, BMR Petroleum Technology Laboratory).

TABLE 2. PALM VALLEY NO. 1 SHALE LOG VALUES

PALM VALLEY -1 0002 17-02-78

SAMPLE NUMBER	DEPTH (MBRT)(FT.BRT)	GAMMA RAY (API UNITS)	RESISTIVITY (OHM-METRE)	CONDUCTIVITY (MILLIMHOS/M)	DENSITY (GM/CC)	SONIC TRAVEL TIME (MUSEC/CM)(MUSEC/FT)	NEUTRON POROSITY INDEX
1	1019.6(3345.)	95.	16.7	60.	.00	2.36 (72.)	800.000
2	1097.3(3600.)	100.	33.3	30.	.00	2.36 (72.)	800.000
3	1223.8(4015.)	85.	30.3	33.	.00	2.62 (80.)	850.000
4	1280.2(4200.)	75.	28.6	35.	.00	2.30 (70.)	900.000
5	1407.3(4617.)	95.	11.8	85.	.00	2.23 (68.)	850.000
6	1463.0(4800.)	90.	25.0	40.	.00	2.30 (70.)	1000.000
7	1507.2(4945.)	70.	14.3	70.	.00	1.80 (55.)	1160.000
8	1551.4(5090.)	90.	50.0	20.	.00	1.64 (50.)	1210.000
9	1673.4(5490.)	120.	62.5	16.	.00	2.36 (72.)	850.000
10	1716.9(5633.)	55.	45.5	22.	.00	2.03 (62.)	1200.000
11	1746.8(5731.)	110.	35.7	28.	.00	2.17 (66.)	1000.000
12	1828.8(6000.)	60.	100.0	10.	.00	2.13 (65.)	1100.000
13	1880.0(6168.)	80.	11.8	85.	.00	2.03 (62.)	850.000
14	1972.7(6472.)	120.	5.6	180.	.00	1.87 (57.)	1950.000

TABLE 3. EAST MEREENIE NO. 1 SHALE LOG VALUES

EAST MEREENIE NO.1 0002 14-02-78

SAMPLE NUMBER	DEPTH (MBRT)(FT.BRT)	GAMMA RAY (API UNITS)	RESISTIVITY (OHM-METRE)	CONDUCTIVITY (MILLIMHOS/M)	DENSITY (GM/CC)	SONIC TRAVEL TIME (MUSEC/CM)(MUSEC/FT)		NEUTRON POROSITY INDEX
1	332.2(1090.)	20.	4.5	220.	.00	3.28	(100.)	.000
2	472.4(1550.)	33.	11.8	85.	.00	2.40	(73.)	.000
3	548.6(1800.)	36.	12.5	80.	.00	2.62	(80.)	.000
4	609.6(2000.)	41.	14.3	70.	.00	2.36	(72.)	.000
5	670.6(2200.)	45.	20.0	50.	.00	2.62	(80.)	.000
6	821.4(2695.)	40.	8.3	120.	.00	2.00	(61.)	.000
7	851.9(2795.)	53.	55.6	18.	.00	2.79	(85.)	.000
8	958.3(3144.)	46.	10.0	100.	.00	2.20	(67.)	.000
9	1054.0(3458.)	31.	10.0	100.	.00	2.10	(64.)	.000
10	1056.4(3466.)	30.	5.9	170.	.00	2.13	(65.)	.000
11	1058.0(3471.)	41.	5.6	180.	.00	2.56	(78.)	.000
12	1160.4(3807.)	43.	13.3	75.	.00	2.00	(61.)	.000
13	1220.7(4005.)	53.	12.5	80.	.00	1.97	(60.)	.000
14	1415.8(4645.)	58.	1.0	1000.	.00	1.77	(54.)	.000

TABLE 4. ASHMORE REEF NO. 1 SHALE LOG VALUES

ASHMORE REEF NO.1 0001 17-02-78

SAMPLE NUMBER	DEPTH (MBRT)(FT.BRT)	GAMMA RAY (API UNITS)	RESISTIVITY (OHM-METRE)	CONDUCTIVITY (MILLIMHOS/M)	DENSITY (GM/CC)	SONIC TRAVEL TIME (MUSEC/CM)	(MUSEC/FT)	NEUTRON POROSITY INDEX
1	332.2(1090.)	25.	2.6	390.	.00	2.76	(84.)	.000
2	917.4(3010.)	20.	2.3	430.	2.49	3.08	(94.)	.000
3	1066.8(3500.)	28.	.7	1500.	2.46	3.28	(100.)	.000
4	1118.6(3670.)	40.	.9	1100.	2.33	3.61	(110.)	.000
5	1236.0(4055.)	10.	1.2	860.	2.20	2.95	(90.)	.000
6	1537.7(5045.)	15.	1.2	840.	2.34	2.56	(78.)	.000
7	1691.6(5550.)	15.	1.1	950.	2.36	2.66	(81.)	.000
8	1830.3(6005.)	14.	2.2	450.	2.45	2.30	(70.)	.000
9	1981.2(6500.)	10.	5.6	180.	2.59	1.97	(60.)	.000
10	2017.8(6620.)	30.	2.0	500.	2.40	2.66	(81.)	.000
11	2154.9(7070.)	20.	3.8	260.	2.56	2.30	(70.)	.000
12	2209.8(7250.)	45.	4.8	210.	2.62	2.43	(74.)	.000
13	2270.8(7450.)	18.	5.0	200.	2.56	2.20	(67.)	.000
14	2438.4(8000.)	60.	6.2	160.	2.54	2.40	(73.)	.000
15	2447.5(8030.)	80.	3.7	270.	2.52	2.62	(80.)	.000
16	2942.8(9655.)	30.	5.6	180.	2.54	2.33	(71.)	.190
17	2959.0(9708.)	50.	12.5	80.	2.62	2.30	(70.)	.220
18	2980.9(9780.)	42.	10.0	100.	2.65	2.20	(67.)	.220
19	2988.6(9805.)	45.	10.0	100.	2.65	2.13	(65.)	.170
20	3023.0(9918.)	35.	4.5	220.	2.62	2.46	(75.)	.240
21	3054.1(10020.)	30.	5.6	180.	2.62	2.26	(69.)	.240
22	3069.3(10070.)	35.	8.3	120.	2.63	2.26	(69.)	.260
23	3148.6(10330.)	35.	8.3	120.	2.59	2.33	(71.)	.200
24	3166.9(10390.)	35.	10.0	100.	2.65	2.26	(69.)	.160
25	3212.6(10540.)	30.	10.0	100.	2.67	2.30	(70.)	.190
26	3226.3(10585.)	30.	7.1	140.	2.55	2.17	(66.)	.130
27	3237.0(10620.)	45.	6.7	150.	2.68	2.43	(74.)	.220
28	3288.2(10788.)	30.	3.6	280.	2.59	2.13	(65.)	.140
29	3304.0(10840.)	30.	6.2	160.	2.60	2.13	(65.)	.120
30	3324.8(10908.)	35.	10.0	100.	2.68	2.26	(69.)	.200
31	3334.5(10940.)	40.	12.5	80.	2.63	2.43	(74.)	.240
32	3361.9(11030.)	35.	12.5	80.	2.75	2.23	(68.)	.190
33	3419.9(11220.)	25.	3.2	310.	2.52	2.07	(63.)	.100
34	3432.0(11260.)	30.	16.7	60.	2.70	2.00	(61.)	.220
35	3456.4(11340.)	30.	9.1	110.	2.65	2.03	(62.)	.190
36	3475.3(11402.)	45.	10.0	100.	2.62	2.07	(63.)	.170
37	3505.2(11500.)	105.	8.3	120.	2.70	1.71	(52.)	.250
38	3613.4(11855.)	105.	50.0	20.	2.65	1.97	(60.)	.260
39	3628.6(11905.)	15.	10.0	100.	2.58	1.90	(58.)	.060
40	3648.5(11970.)	45.	100.0	10.	2.82	1.77	(54.)	.100
41	3666.7(12030.)	45.	25.0	40.	2.71	1.97	(60.)	.100

TABLE 5. PELICAN NO. 1 SHALE LOG VALUES

PELICAN NO.1 0001 17-02-78

SAMPLE NUMBER	DEPTH (MBRT)(FT.BRT)	GAMMA RAY (API UNITS)	RESISTIVITY (OHM-METRE)	CONDUCTIVITY (MILLIMHOS/M)	DENSITY (GM/CC)	SONIC TRAVEL TIME (MUSEC/CM)	(MUSEC/FT)	NEUTRON POROSITY INDEX
1	1676.4(5500.)	47.	1.0	1000.	2.14	4.23	(129.)	.000
2	1752.6(5750.)	50.	1.4	700.	2.10	3.77	(115.)	.000
3	1777.0(5830.)	40.	.6	1600.	2.27	3.54	(108.)	.000
4	1847.1(6060.)	75.	2.3	440.	2.48	3.18	(97.)	.000
5	1931.2(6336.)	70.	2.8	360.	2.15	2.89	(88.)	.000
6	2018.4(6622.)	60.	1.8	560.	2.47	2.92	(89.)	.000
7	2133.6(7000.)	75.	2.5	400.	2.40	2.79	(85.)	.000
8	2284.2(7494.)	60.	4.2	240.	2.50	2.72	(83.)	740.000
9	2343.9(7690.)	60.	5.0	200.	2.50	2.66	(81.)	780.000
10	2453.0(8048.)	90.	8.3	120.	2.53	2.62	(80.)	730.000
11	2578.6(8460.)	65.	10.0	100.	2.55	2.56	(78.)	730.000
12	2712.7(8900.)	75.	5.6	180.	2.50	2.56	(78.)	750.000
13	2834.6(9300.)	90.	5.7	175.	2.60	2.59	(79.)	900.000
14	2883.4(9460.)	78.	6.7	150.	2.62	2.49	(76.)	840.000
15	2987.0(9800.)	80.	8.0	125.	2.63	2.49	(76.)	960.000
16	3048.0(10000.)	75.	8.0	125.	2.58	2.49	(76.)	1000.000
17	3078.5(10100.)	60.	10.0	100.	2.60	2.62	(80.)	1000.000
18	3163.8(10380.)	65.	6.7	150.	2.60	2.46	(75.)	1010.000

TABLE 6. ROB ROY NO. 1 SHALE LOG VALUES

ROB ROY NO.1 0001 17-02-78

SAMPLE NUMBER	DEPTH (MBRT)(FT.BRT)	GAMMA RAY (API UNITS)	RESISTIVITY (OHM-METRE)	CONDUCTIVITY (MILLIMHOS/M)	DENSITY (GM/CC)	SONIC TRAVEL TIME (MUSEC/CM)	(MUSEC/FT)	NEUTRON POROSITY INDEX
1	467.3(1533.)	38.	.8	1250.	.00	4.59	(140.)	.000
2	641.3(2104.)	50.	1.0	1000.	.00	3.90	(119.)	.000
3	781.2(2563.)	50.	1.0	1000.	.00	3.84	(117.)	.000
4	832.1(2730.)	45.	.7	1429.	.00	5.25	(160.)	.000
5	853.4(2800.)	40.	.7	1429.	.00	5.12	(156.)	.000
6	914.4(3000.)	45.	.6	1667.	.00	4.82	(147.)	.000
7	1066.8(3500.)	50.	.7	1429.	.00	4.27	(130.)	.000
8	1219.8(4002.)	55.	.6	1667.	.00	4.53	(138.)	.000
9	1325.9(4350.)	47.	.2	5000.	2.21	3.94	(120.)	.000
10	1450.8(4760.)	90.	1.2	833.	2.00	4.13	(126.)	.000
11	1542.3(5060.)	75.	1.3	769.	2.07	4.13	(126.)	.000
12	1575.8(5170.)	75.	2.1	476.	2.47	3.18	(97.)	.000
13	1630.7(5350.)	100.	2.8	357.	2.52	2.95	(90.)	.000
14	1676.4(5500.)	58.	3.0	333.	2.50	2.46	(75.)	.000
15	1746.5(5730.)	105.	4.0	250.	2.65	2.62	(80.)	.000
16	1816.6(5960.)	105.	3.2	312.	2.61	2.79	(85.)	.000
17	1889.8(6200.)	106.	2.8	357.	2.62	2.79	(85.)	.000
18	2011.7(6600.)	130.	4.0	250.	2.67	2.62	(80.)	.000
19	2103.1(6900.)	85.	10.0	100.	2.65	2.23	(68.)	.000
20	2203.7(7230.)	110.	9.0	111.	2.72	2.33	(71.)	.000
21	2252.5(7390.)	145.	28.0	36.	2.65	2.13	(65.)	.000

TABLE 7. SAHUL SHOALS SHALE LOG VALUES

SAHUL SHOALS-1 SHALE PROPERTIES 0001 17-02-78

SAMPLE NUMBER	DEPTH (MBRT)(FT.BRT)	GAMMA RAY (API UNITS)	RESISTIVITY (OHM-METRE)	CONDUCTIVITY (MILLIMHOS/M)	DENSITY (GM/CC)	SONIC TRAVEL TIME (MUSEC/CM)	(MUSEC/FT)	NEUTRON POROSITY INDEX
1	993.6(3260.)	20.	1.1	900.	2.00	3.12	(95.)	.450
2	1059.2(3475.)	20.	1.4	720.	2.26	2.76	(84.)	.300
3	1534.7(5035.)	40.	1.0	1000.	2.40	3.90	(119.)	.480
4	1635.3(5365.)	26.	1.3	760.	2.43	3.44	(105.)	.360
5	1778.5(5835.)	50.	1.2	820.	2.35	3.64	(111.)	.450
6	1966.0(6450.)	115.	2.0	500.	2.45	2.99	(91.)	.300
7	2008.6(6590.)	115.	2.1	480.	2.48	2.85	(87.)	.210
8	2136.6(7010.)	100.	2.6	390.	2.50	2.85	(87.)	.240
9	2240.3(7350.)	75.	6.7	150.	2.54	2.49	(76.)	.180
10	2340.9(7680.)	115.	4.2	240.	2.52	2.69	(82.)	.180
11	2377.4(7800.)	115.	3.3	300.	2.36	2.66	(81.)	.210
12	2606.0(8550.)	85.	4.0	250.	2.54	2.62	(80.)	.190
13	2712.7(8900.)	85.	3.8	260.	2.58	2.62	(80.)	.190
14	2815.7(9238.)	36.	4.0	250.	2.58	3.22	(98.)	.190
15	2902.3(9522.)	38.	3.6	280.	2.15	3.67	(112.)	.190
16	2912.4(9555.)	30.	5.0	200.	2.44	3.77	(115.)	.190
17	3035.8(9960.)	50.	5.6	180.	2.63	2.49	(76.)	.190
18	3134.9(10285.)	40.	14.3	70.	2.30	2.53	(77.)	.270
19	3380.2(11090.)	70.	13.3	75.	2.68	2.30	(70.)	.250
20	3465.6(11370.)	70.	9.1	110.	2.67	2.26	(69.)	.250
21	3572.3(11720.)	70.	12.5	80.	2.72	2.30	(70.)	.210
22	3627.1(11900.)	70.	14.3	70.	2.72	2.30	(70.)	.200
23	3639.3(11940.)	70.	9.1	110.	2.70	2.69	(82.)	.190
24	3700.3(12140.)	70.	5.0	200.	2.70	3.12	(95.)	.170
25	3739.9(12270.)	70.	4.0	250.	2.70	2.95	(90.)	.150

Fig. 1

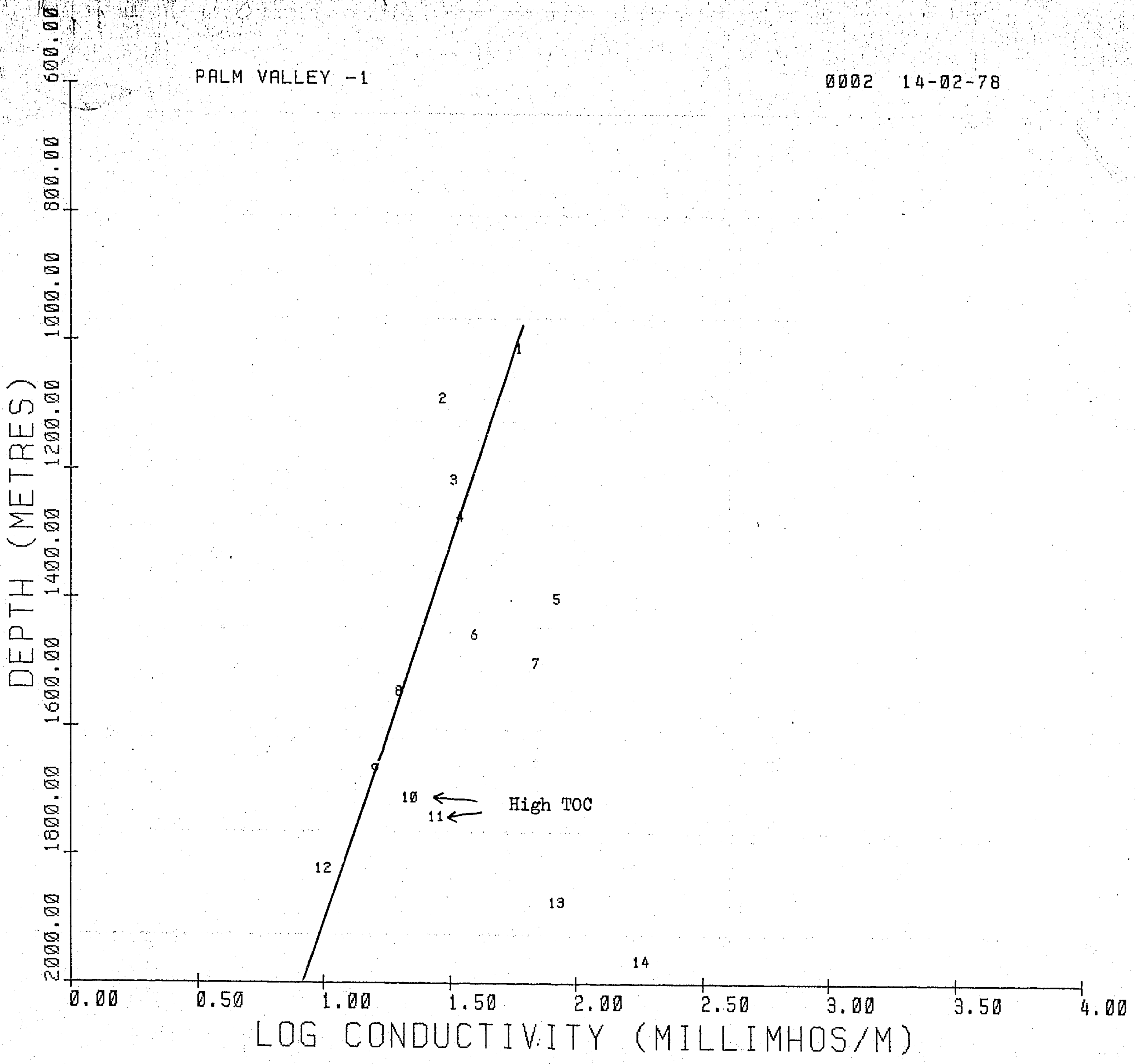
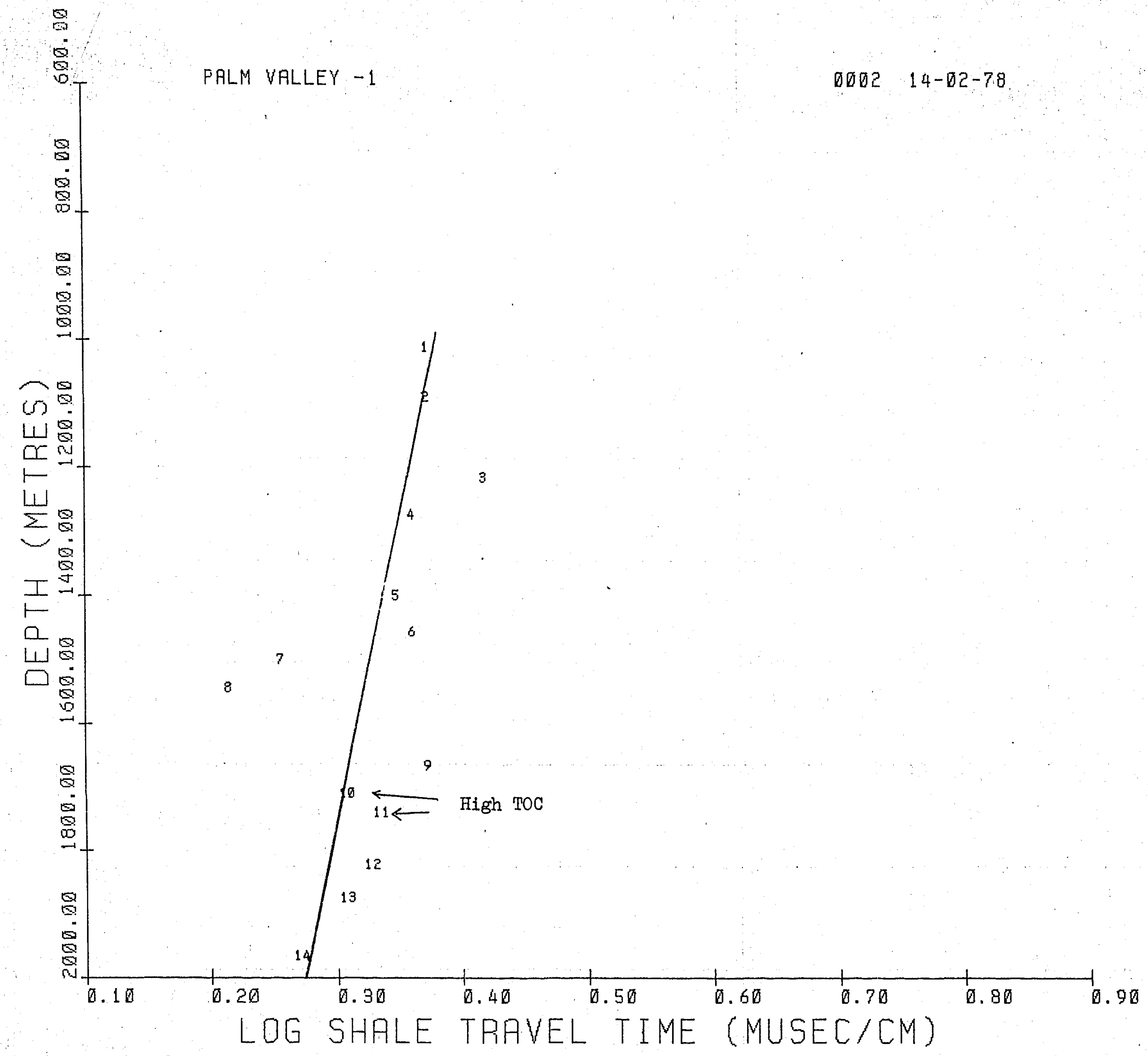

PALM VALLEY -1
0002 14-02-78
DEPTH (METRES)
600.00
800.00
1000.00
1200.00
1400.00
1600.00
1800.00
2000.00
LOG CONDUCTIVITY (MILLIMHOS/M)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
High TOC

Fig. 2


PALM VALLEY -1
0002 14-02-78
DEPTH (METRES)
600.00
800.00
1000.00
1200.00
1400.00
1600.00
1800.00
2000.00
LOG SHALE TRAVEL TIME (MUSEC/CM)
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1
2
3
4
5
6
7
8
9
10
11
12
13
14
High TOC

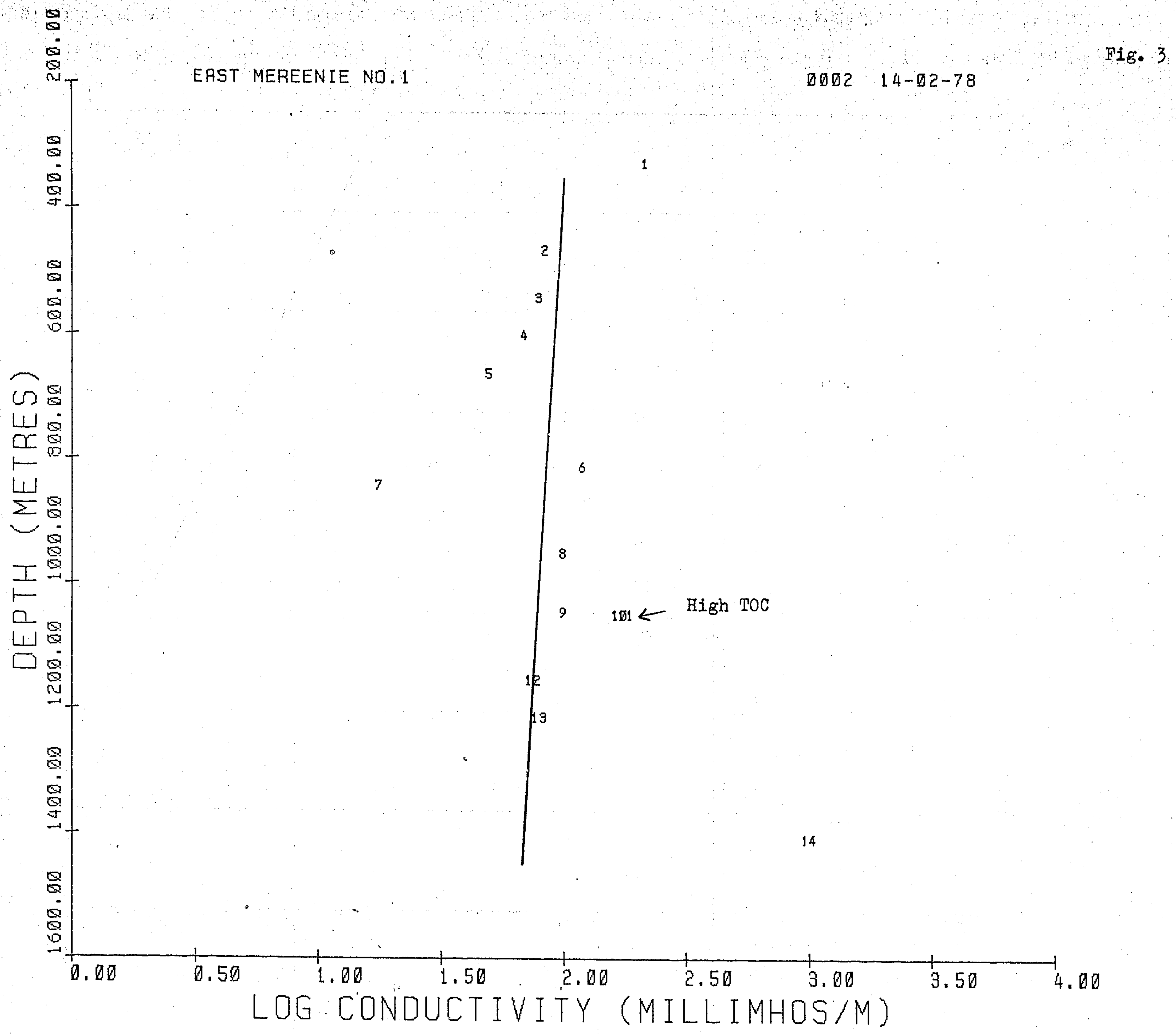
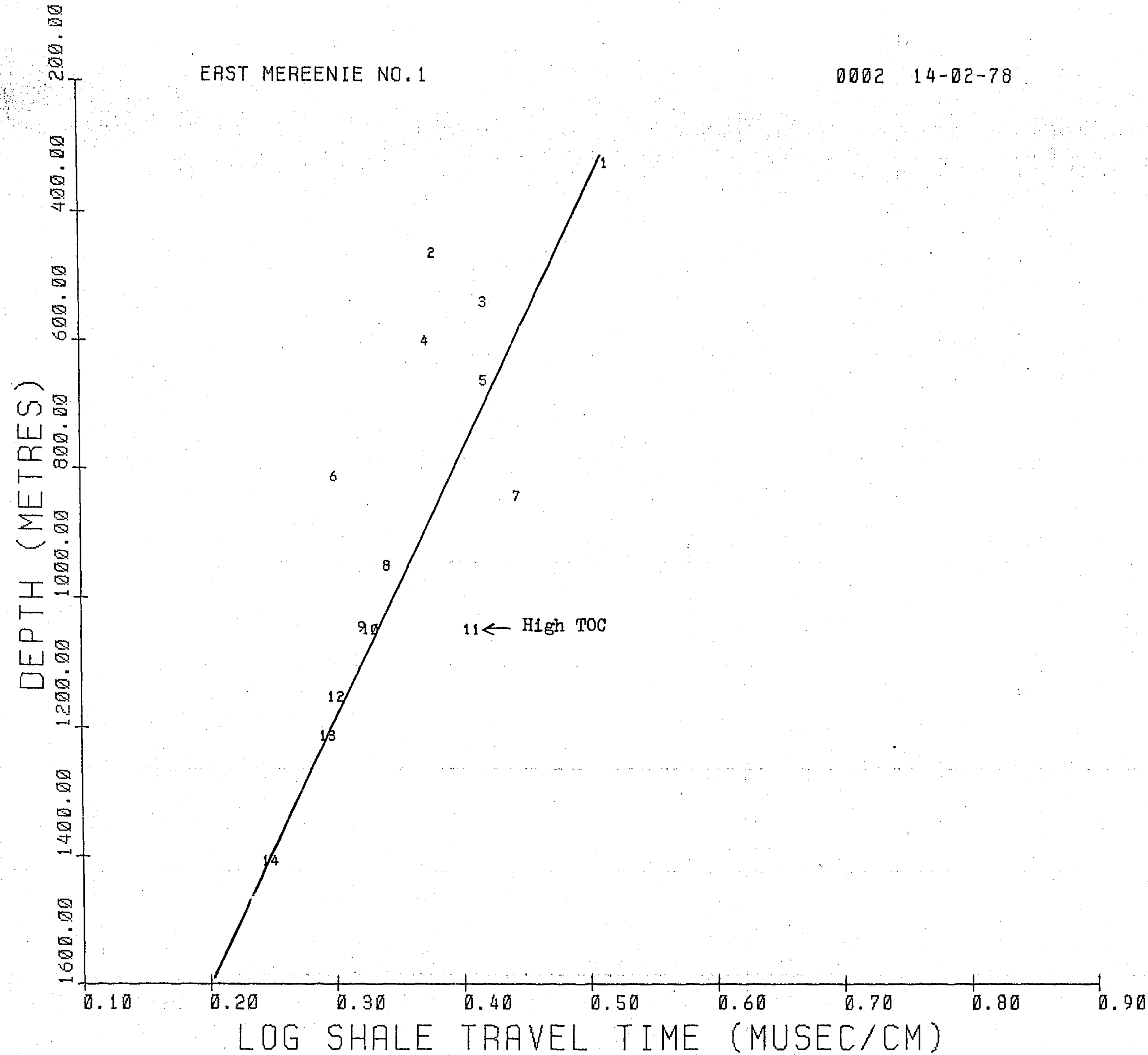


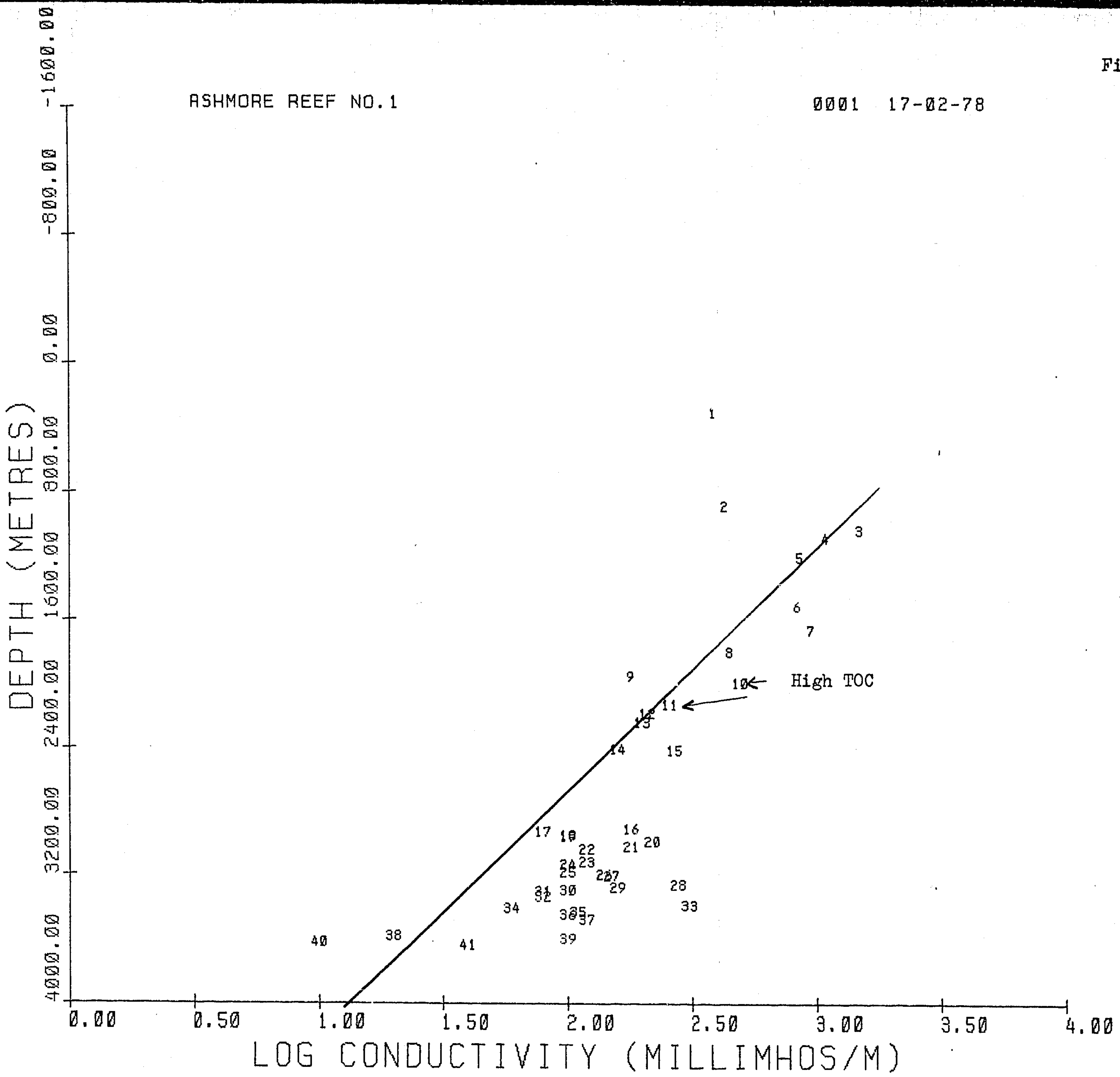
Fig. 3
EAST MEREENIE NO.1
0002 14-02-78
DEPTH (METRES)
200.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
LOG CONDUCTIVITY (MILLIMHOS/M)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
1
2
3
4
5
6
7
8
9
101
High TOC
12
13
14

Fig. 4



EAST MEREENIE NO.1
0002 14-02-78
DEPTH (METRES)
200.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
1
2
3
4
5
6
7
8
9
10
11
High TOC
12
13
14
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
LOG SHALE TRAVEL TIME (MUSEC/CM)

Fig. 5



ASHMORE REEF NO.1
0001 17-02-78
DEPTH (METRES)
LOG CONDUCTIVITY (MILLIMHOS/M)
High TOC
-1600.00
-800.00
0.00
800.00
1600.00
2400.00
3200.00
4000.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00

Fig. 6

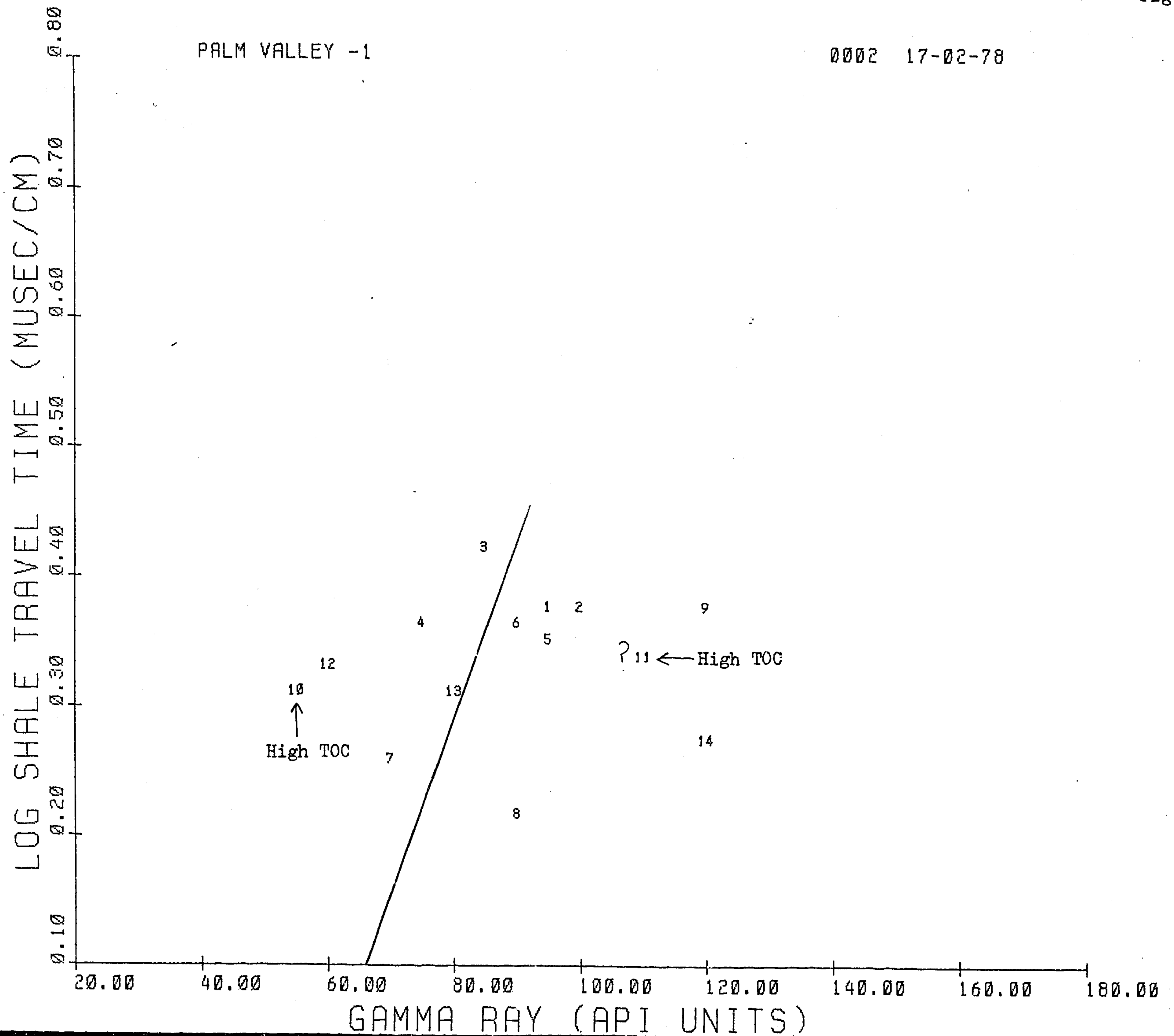

PALM VALLEY -1
0002 17-02-78
LOG SHALE TRAVEL TIME (MUSEC/CM)
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
3
4
6
1
2
9
5
? 11 ← High TOC
12
10
↑
High TOC
13
7
14
8
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
GAMMA RAY (API UNITS)

Fig. 7

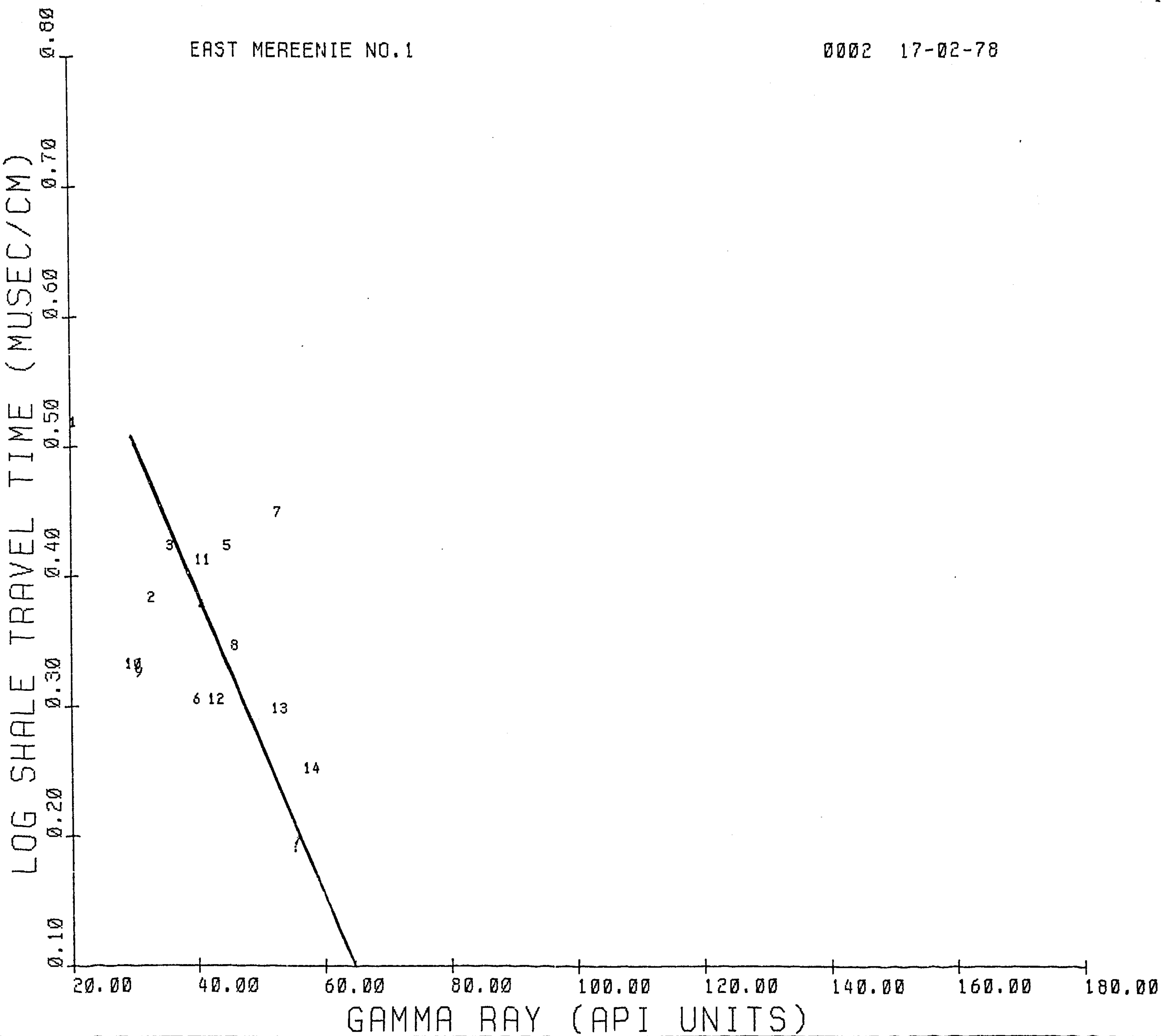
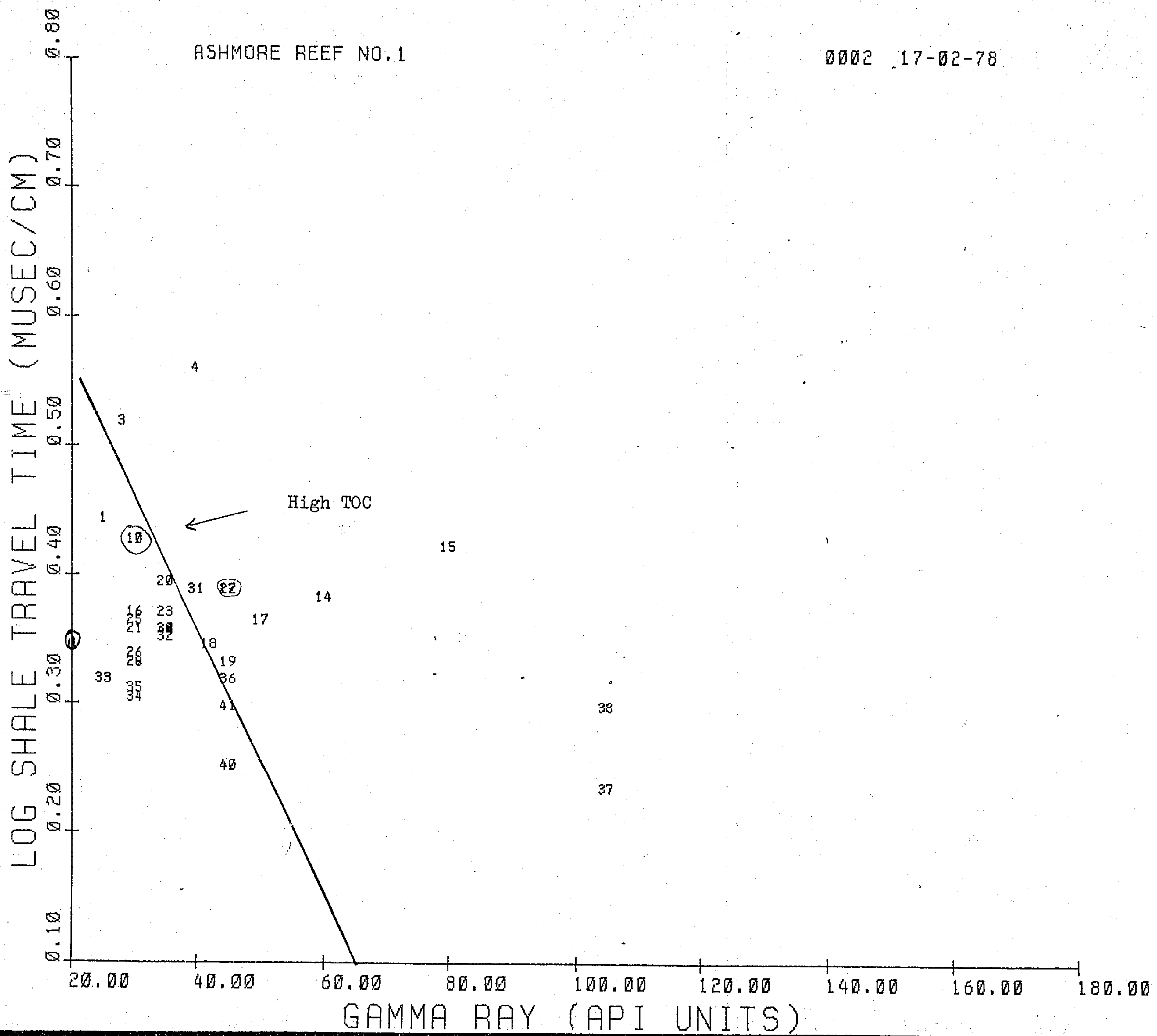

EAST MEREENIE NO.1
0002 17-02-78
LOG SHALE TRAVEL TIME (MUSEC/CM)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
1
2
3
5
6
7
8
9
10
11
12
13
14
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
GAMMA RAY (API UNITS)

Fig. 8



ASHMORE REEF NO.1
0002 17-02-78
High TOC
LOG SHALE TRAVEL TIME (MUSEC/CM)
GAMMA RAY (API UNITS)
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
1
3
4
10
14
15
16
17
18
19
20
21
22
23
26
28
31
32
33
34
35
36
37
38
40
41

Fig. 9

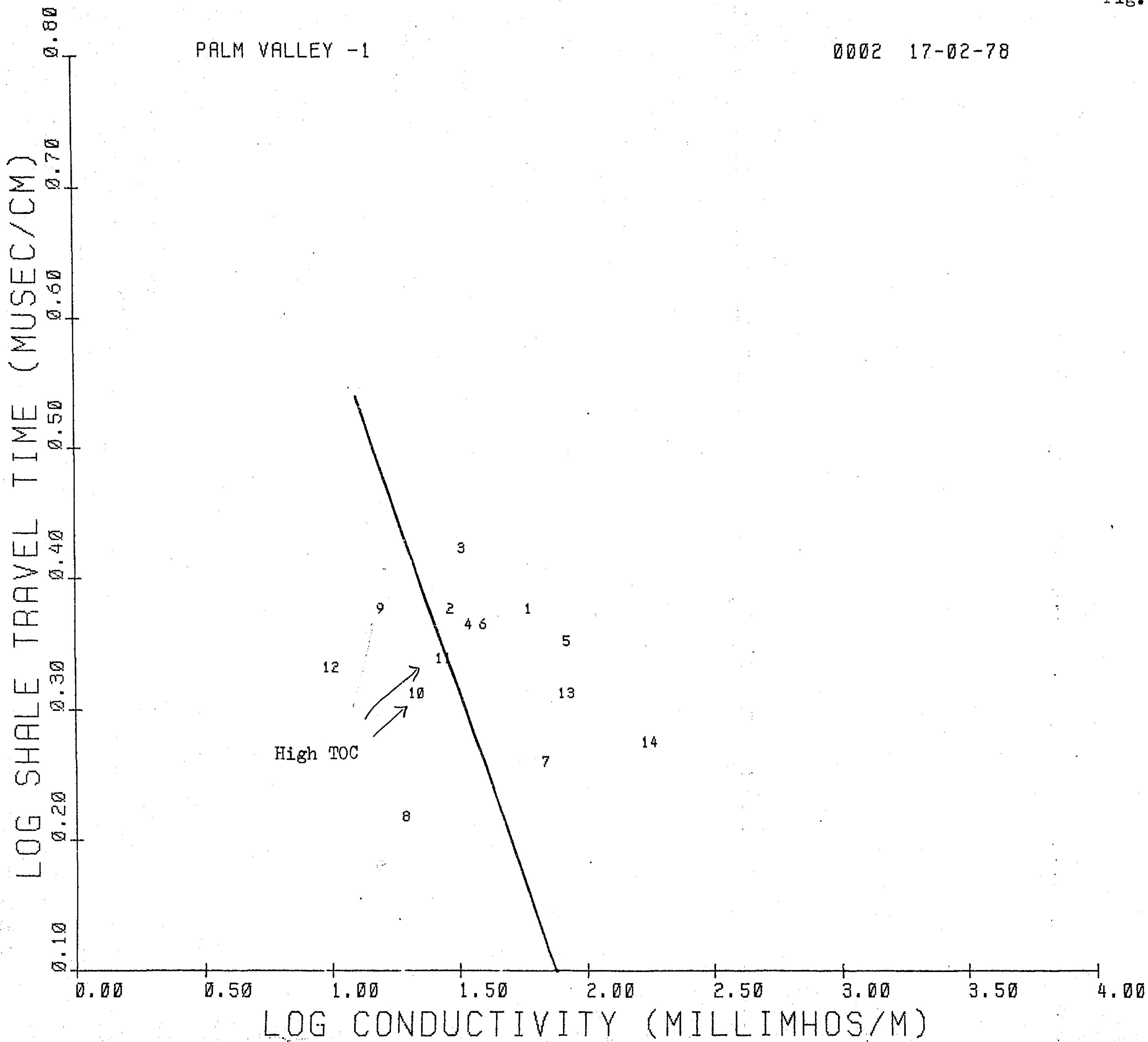

PALM VALLEY -1
0002 17-02-78
LOG SHALE TRAVEL TIME (MUSEC/CM)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
LOG CONDUCTIVITY (MILLIMHOS/M)
3
9
2
1
4 6
5
12
11
10
13
High TOC
14
7
8

Fig. 10

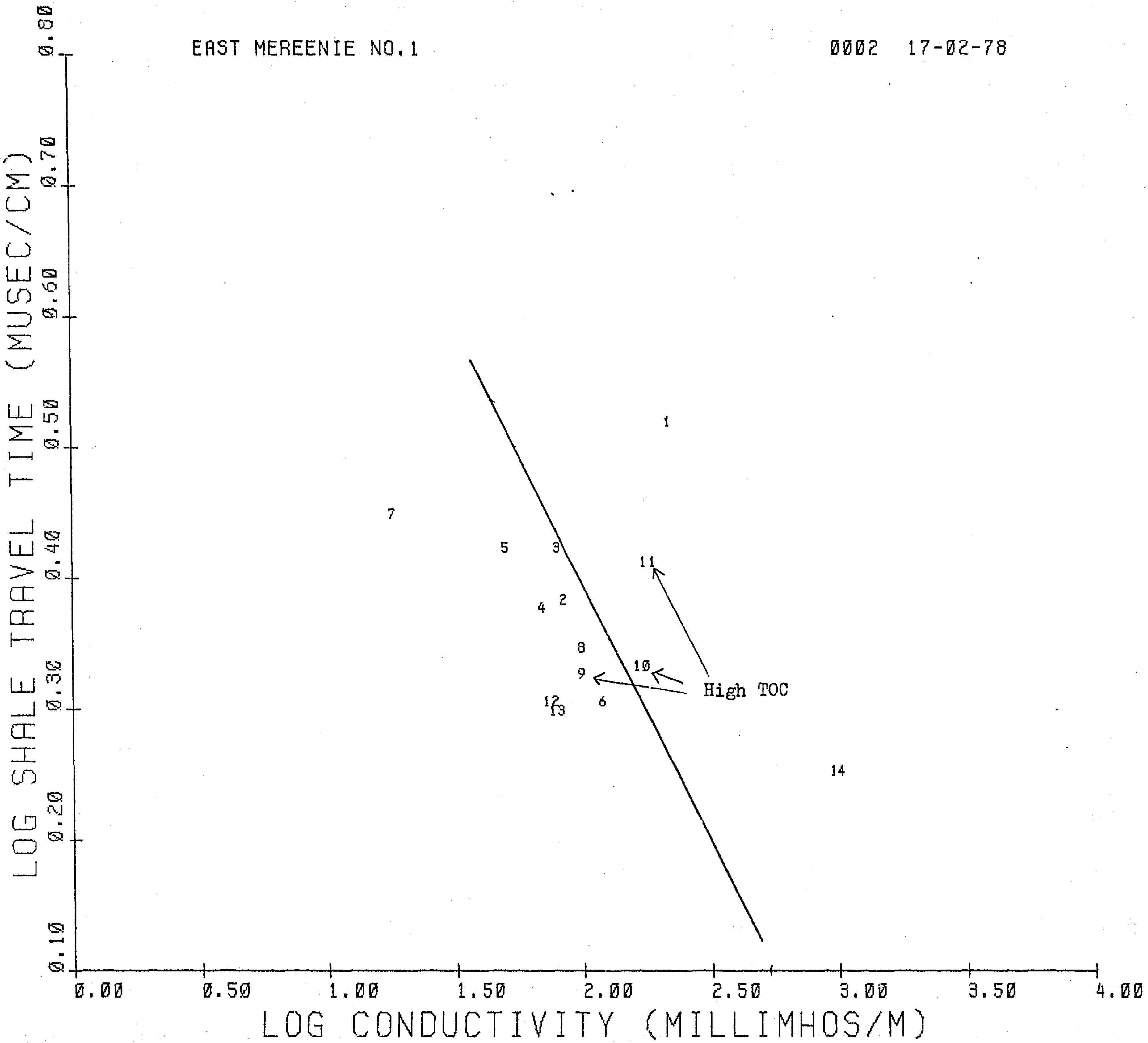

EAST MEREENIE NO.1
0002 17-02-78
LOG SHALE TRAVEL TIME (MUSEC/CM)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
1
7
5
3
11
2
4
8
10
9
High TOC
12
13
6
14
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
LOG CONDUCTIVITY (MILLIMHOS/M)

Fig. 11

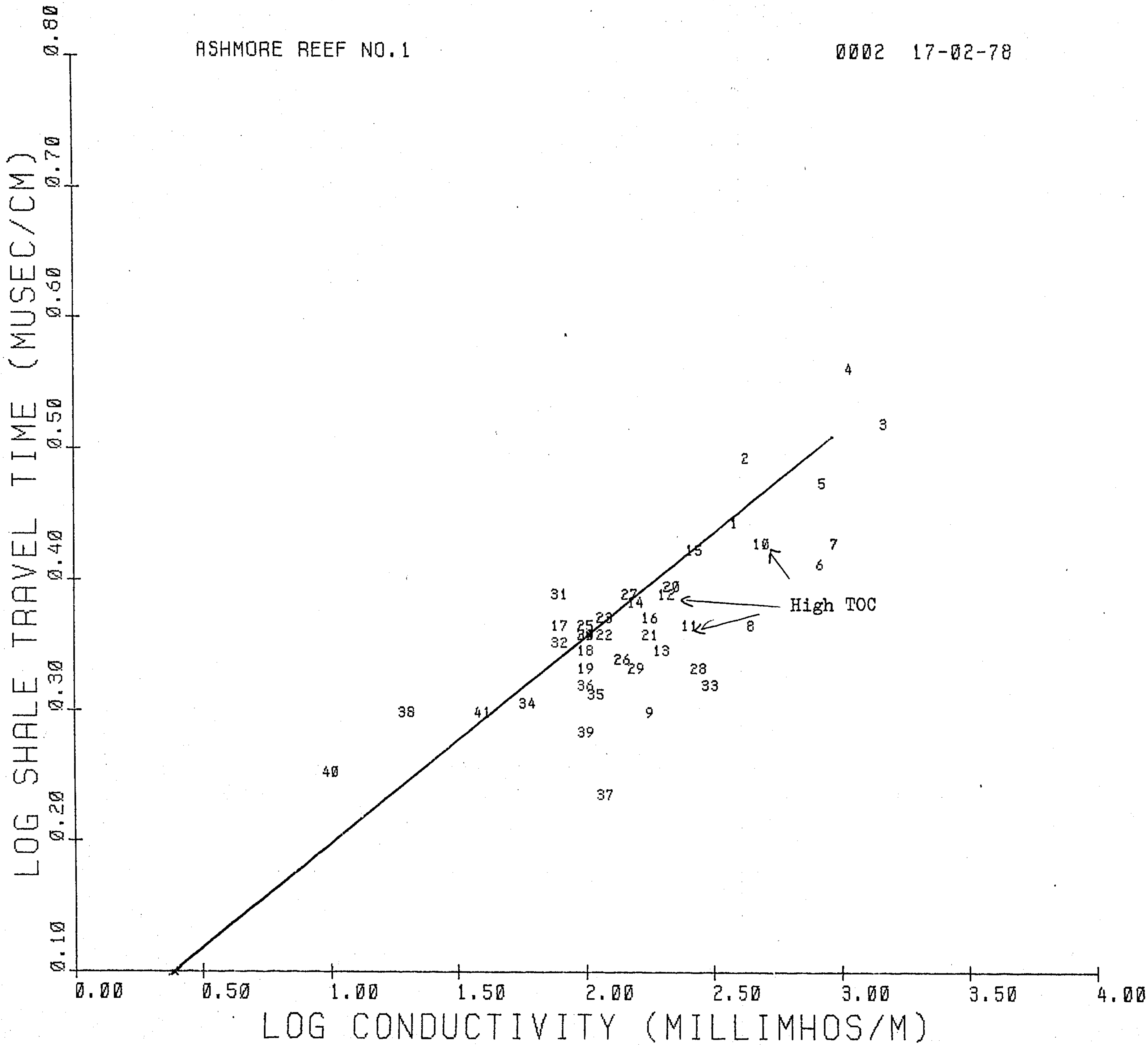

ASHMORE REEF NO.1
0002 17-02-78
LOG SHALE TRAVEL TIME (MUSEC/CM)
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
LOG CONDUCTIVITY (MILLIMHOS/M)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
High TOC
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
25
26
27
28
29
31
32
33
34
35
36
37
38
39
40
41

Fig. 12

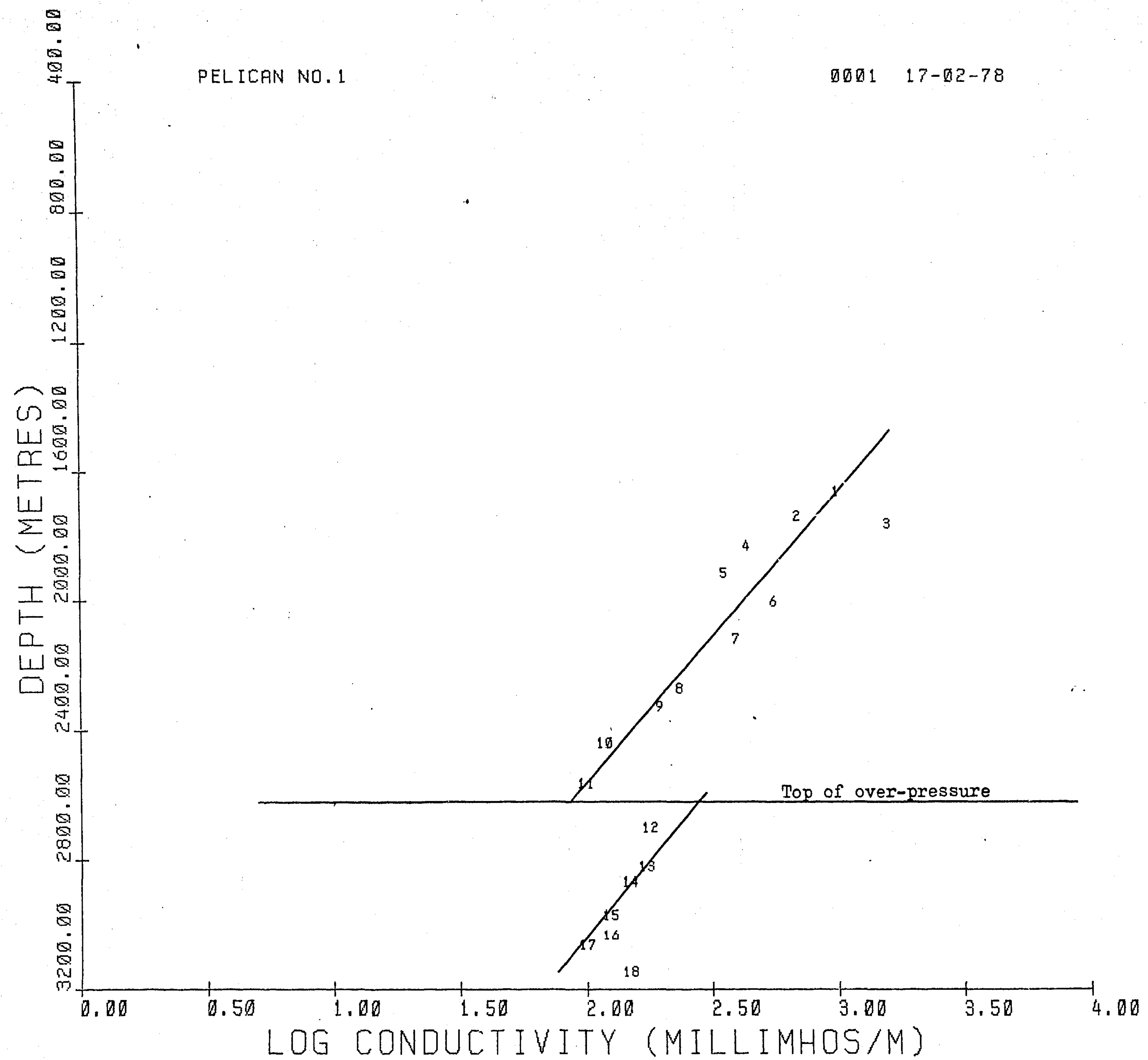

PELICAN NO.1
0001 17-02-78
DEPTH (METRES)
400.00
800.00
1200.00
1600.00
2000.00
2400.00
2800.00
3200.00
LOG CONDUCTIVITY (MILLIMHOS/M)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Top of over-pressure
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Fig. 13

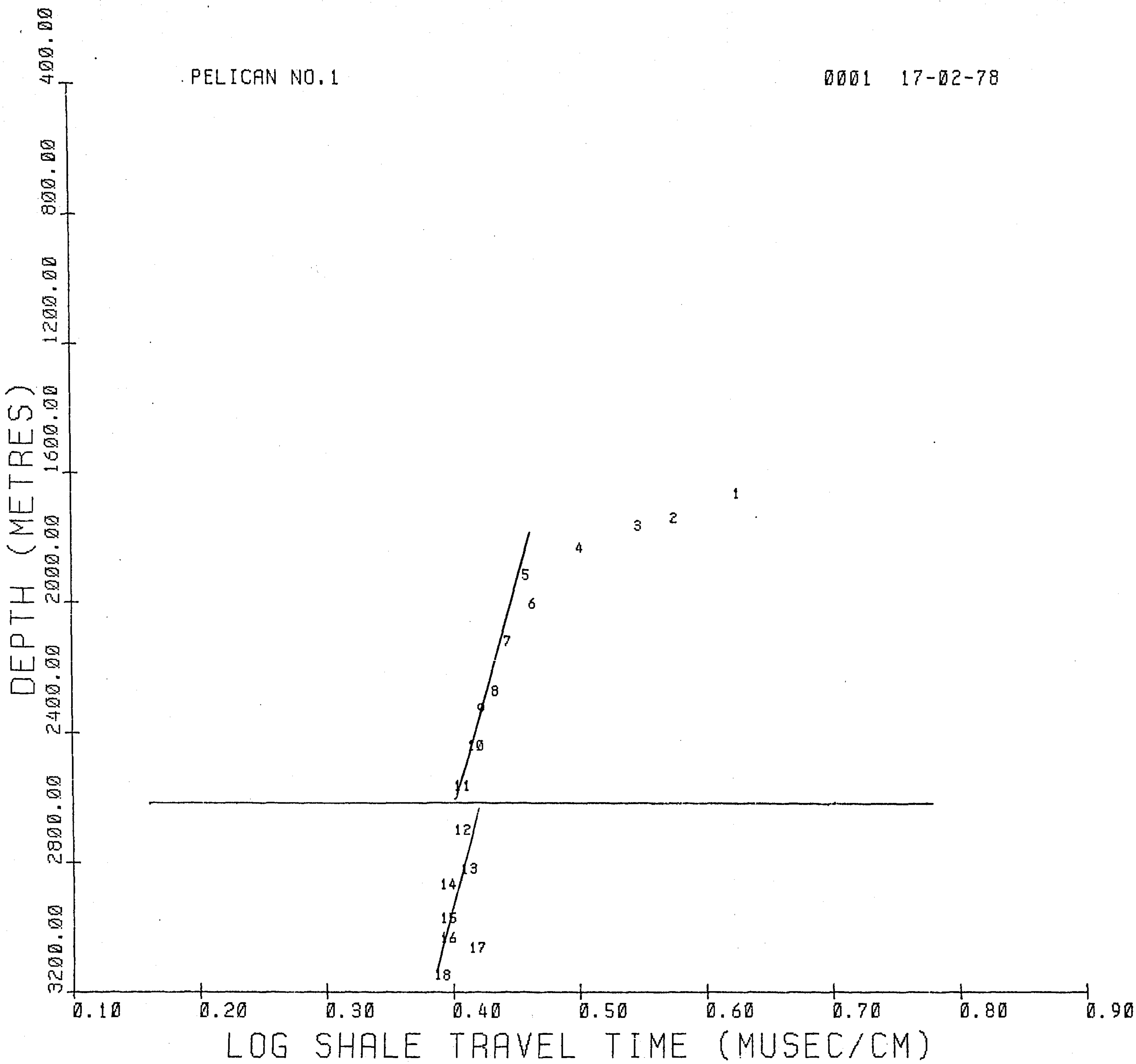
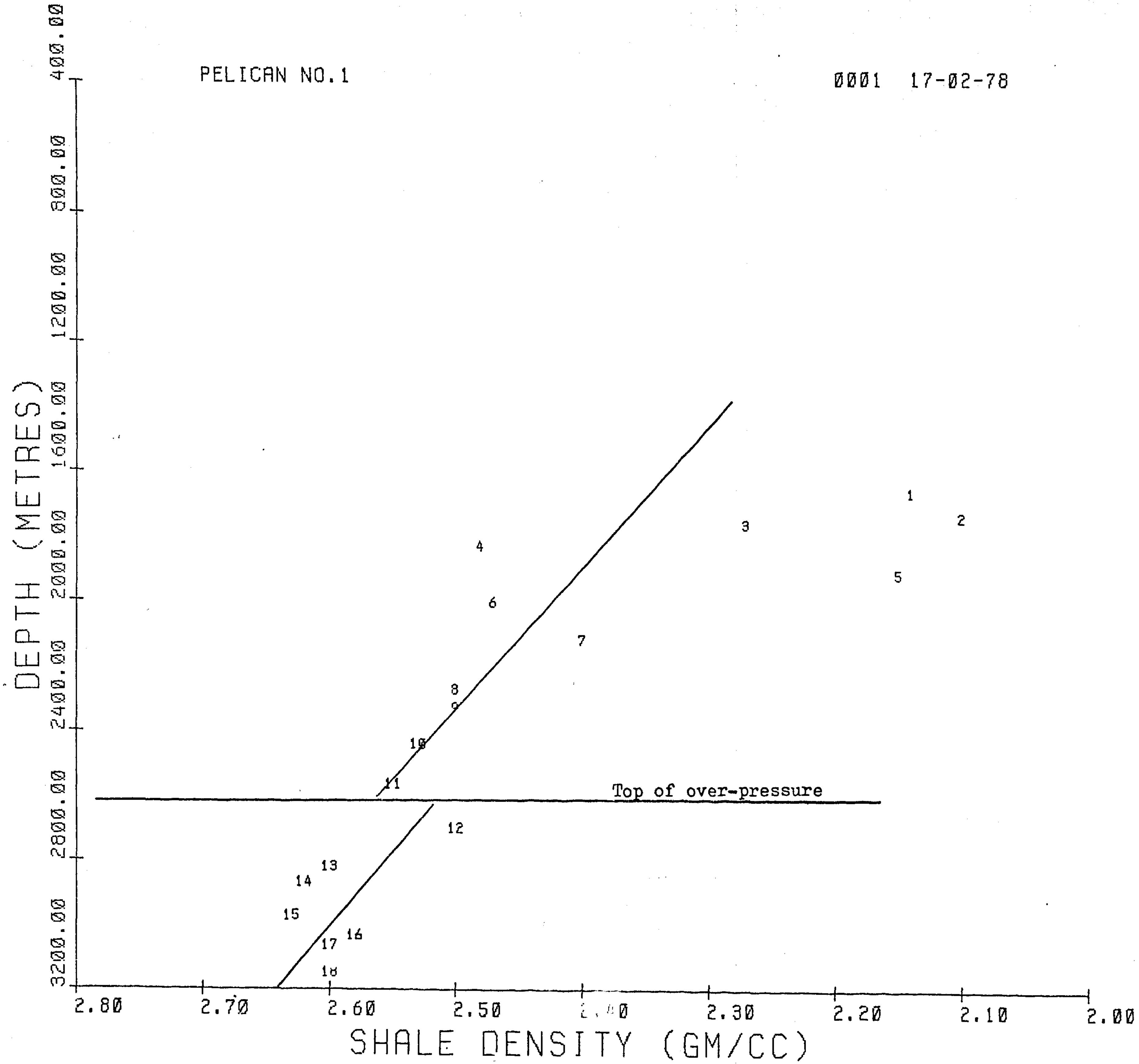

PELICAN NO.1
0001 17-02-78
DEPTH (METRES)
400.00
800.00
1200.00
1600.00
2000.00
2400.00
2800.00
3200.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
LOG SHALE TRAVEL TIME (MUSEC/CM)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Fig. 14



PELICAN NO.1
0001 17-02-78
DEPTH (METRES)
400.00
800.00
1200.00
1600.00
2000.00
2400.00
2800.00
3200.00
SHALE DENSITY (GM/CC)
2.80
2.70
2.60
2.50
2.30
2.20
2.10
2.00
Top of over-pressure
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Fig. 15

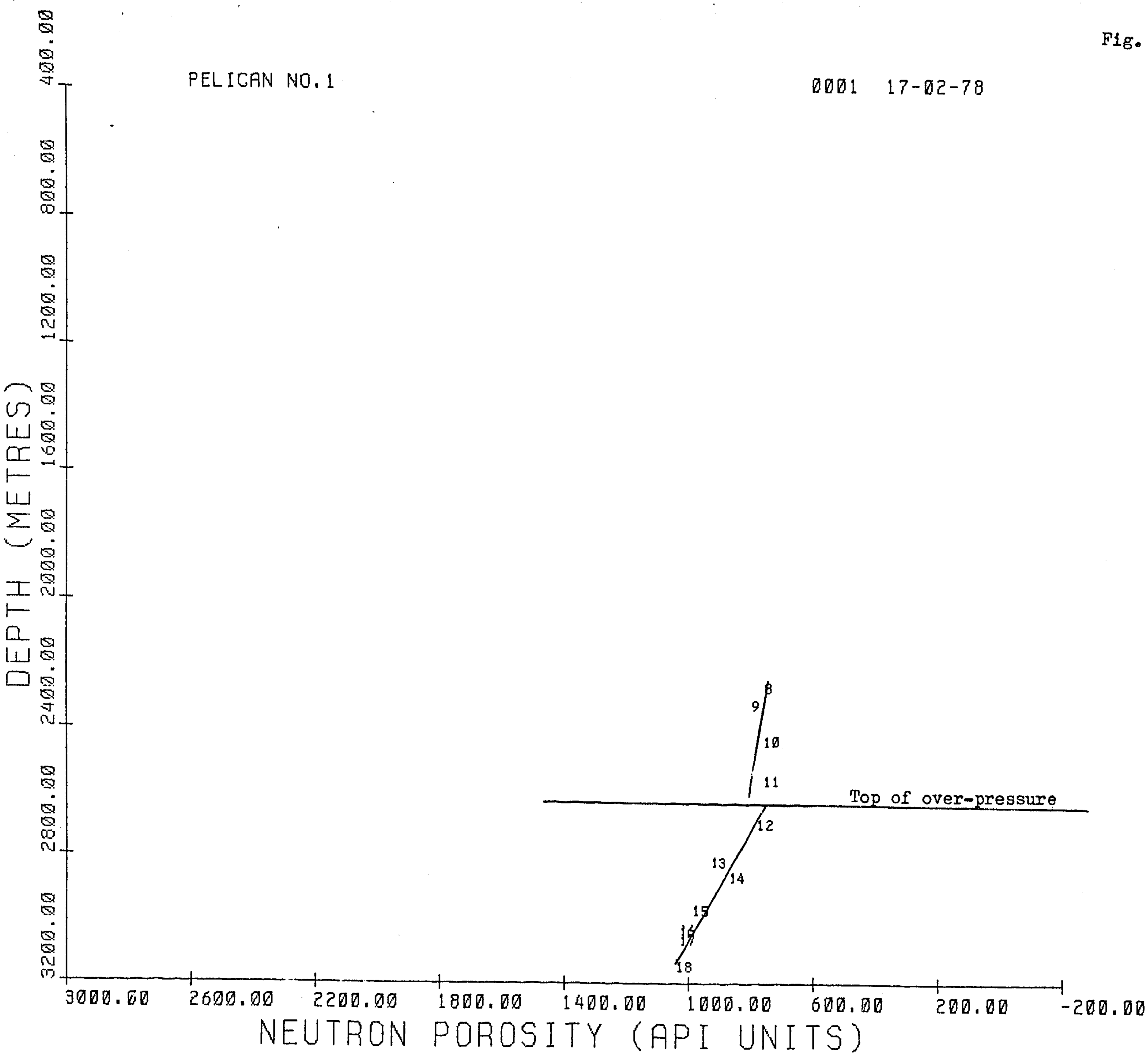
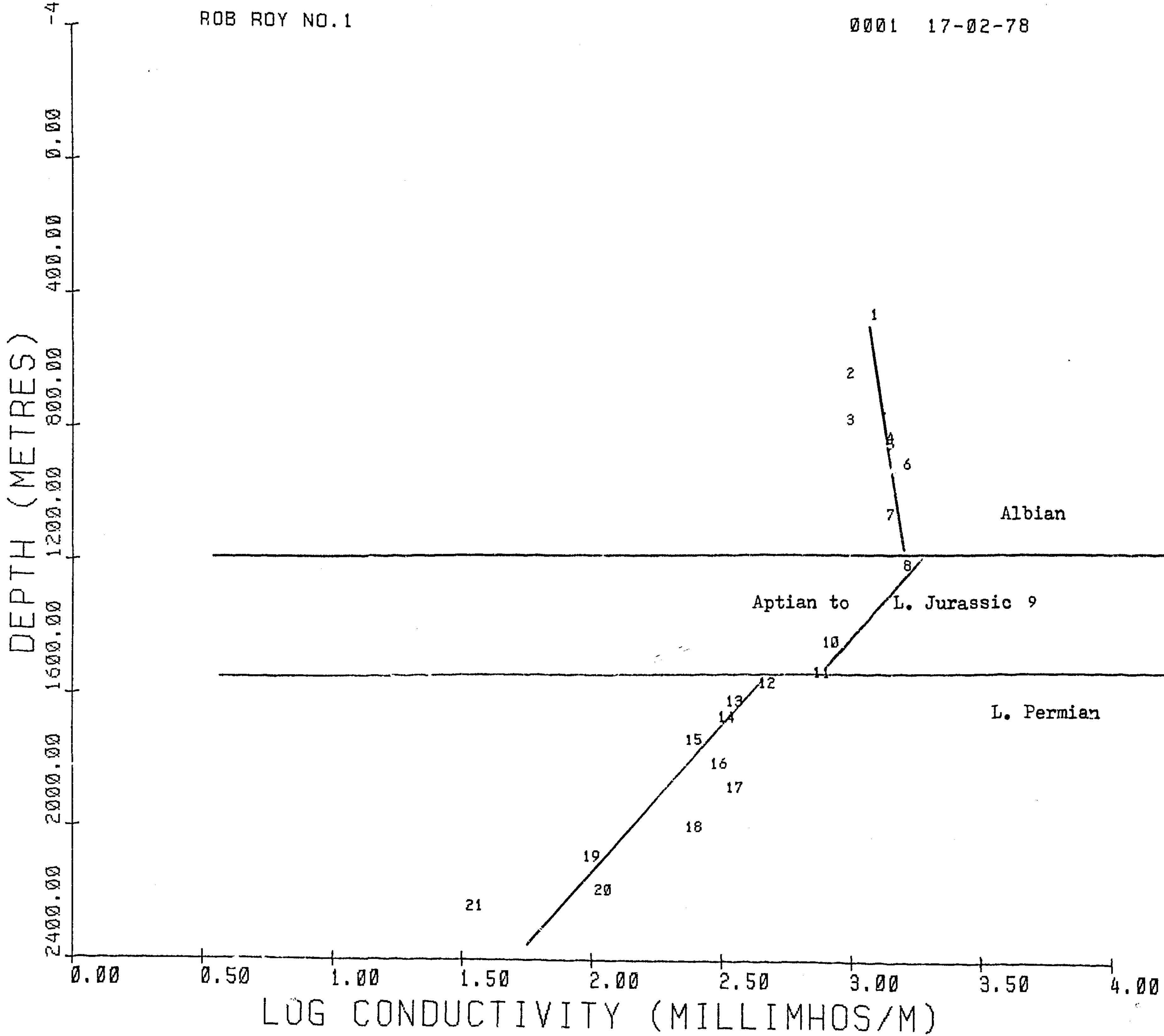

PELICAN NO.1
0001 17-02-78
DEPTH (METRES)
400.00
800.00
1200.00
1600.00
2000.00
2400.00
2800.00
3200.00
3000.00
2600.00
2200.00
1800.00
1400.00
1000.00
600.00
200.00
-200.00
NEUTRON POROSITY (API UNITS)
Top of over-pressure
8
9
10
11
12
13
14
15
16
17
18

Fig. 16



ROB ROY NO.1
0001 17-02-78
DEPTH (METRES)
-400.00
0.00
400.00
800.00
1200.00
1600.00
2000.00
2400.00
1
2
3
4
5
6
7
Albian
8
Aptian to L. Jurassic
9
10
11
12
L. Permian
13
14
15
16
17
18
19
20
21
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
LOG CONDUCTIVITY (MILLIMHOS/M)

Fig. 17

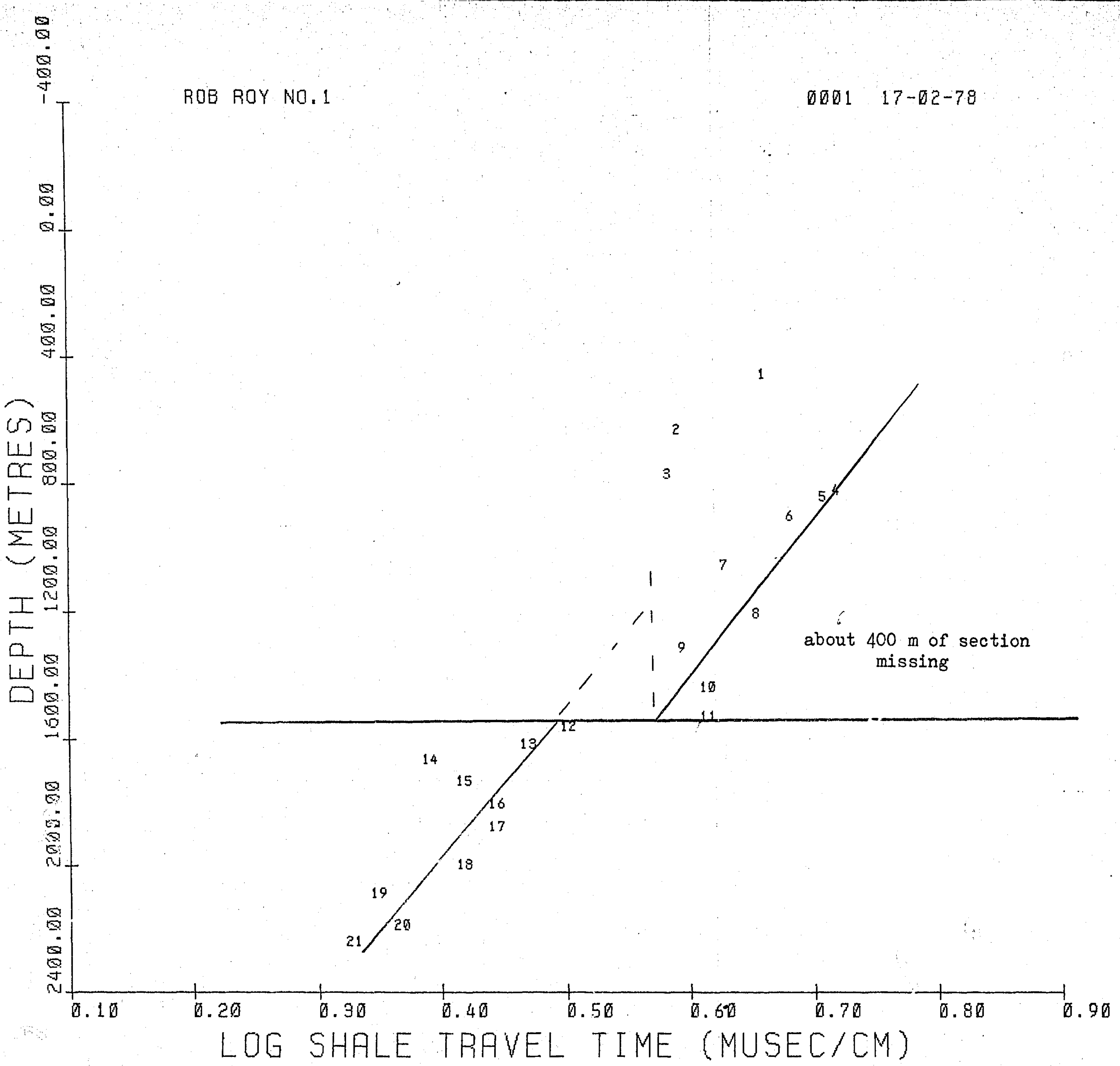

ROB ROY NO.1
0001 17-02-78
DEPTH (METRES)
-400.00
0.00
400.00
800.00
1200.00
1600.00
2000.00
2400.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
about 400 m of section missing
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
LOG SHALE TRAVEL TIME (MUSEC/CM)

Fig. 18

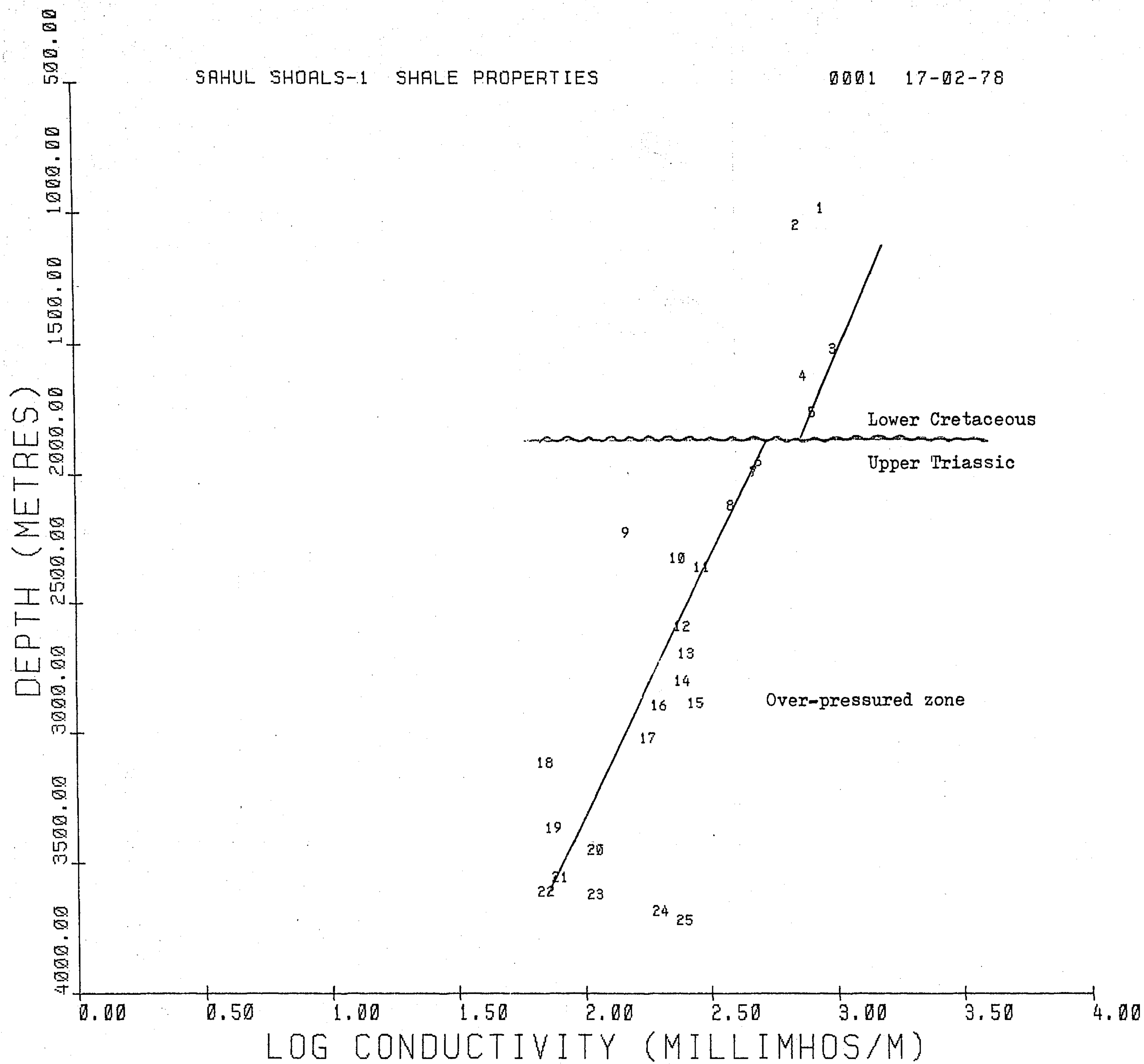
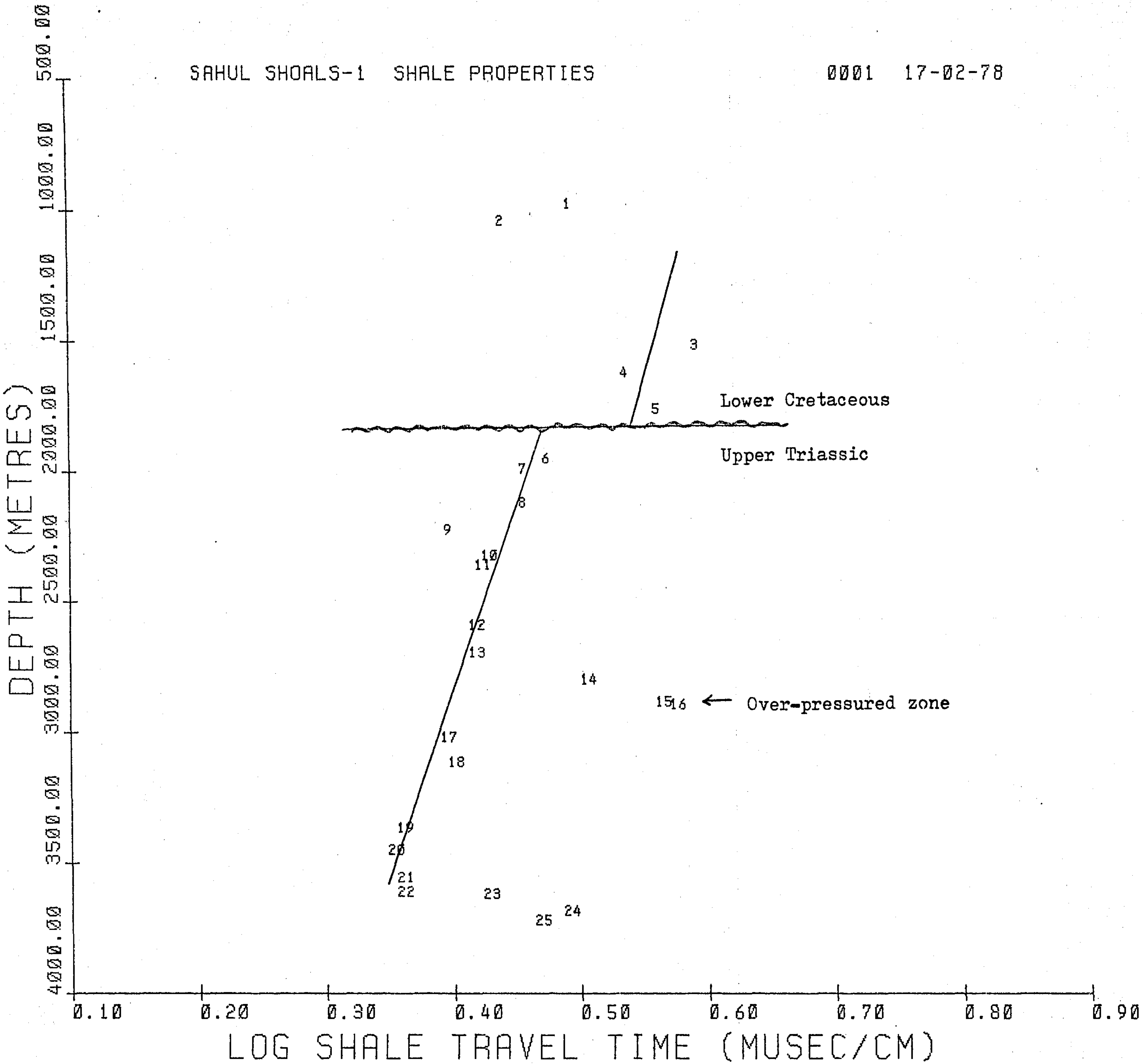

SAHUL SHOALS-1 SHALE PROPERTIES
0001 17-02-78
DEPTH (METRES)
500.00
1000.00
1500.00
2000.00
2500.00
3000.00
3500.00
4000.00
LOG CONDUCTIVITY (MILLIMHOS/M)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Lower Cretaceous
Upper Triassic
Over-pressured zone
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

Fig. 19


SAHUL SHOALS-1 SHALE PROPERTIES
0001 17-02-78
DEPTH (METRES)
500.00
1000.00
1500.00
2000.00
2500.00
3000.00
3500.00
4000.00
LOG SHALE TRAVEL TIME (MUSEC/CM)
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
Lower Cretaceous
Upper Triassic
Over-pressured zone

```
APPENDIX 1: SOURCE CODE LISTING OF PROGRAM SRPL
           ⌂TERMINAL     50
      OUTPUT LOGICAL UNIT =      6
```

```
FTN4,B
      PROGRAM SRPL
C     SOURCE ROCK POTENTIAL LOG PROGRAM
C     PREPARED BY L.E.KURYLOWICZ--DEC.1977
C     ---------------LIST OF PARAMETERS-----------------
C     CD - CONDUCTIVITY (MILLIMHOS/METRE)
C     DENA - DENSITY (GM/CC)
C     DPH - DEPTH (FT BELOW RT)
C     DPHM - DEPTH (METRES BELOW RT)
C     GR - GAMMA RAY READING (API UNITS)
C     ICDL - CONDUCTIVITY READINGS SWITCH (1=YES;0=NO)
C     IPL - PLOT SWITCH (1=YES;0=NO)
C     MDPH - METRIC DEPTH SWITCH (1=YES;0=NO)
C     MTAC - METRIC SONIC READINGS SWITCH (1=YES;0=NO)
C     NAMEF - SOURCE ROCK DATA FILE NAME
C     NLTYPE - NEUTRON LOG TYPE(0-NONE;1-API UNITS;2-SNP OR CNL)
C     NPLOT- NUMBER OF PLOTS(1:Y VS. DEPTH; 2:X-PLOTS)
C     RD - DEEP RESISTIVITY READINGS (OHM-METRE)
C     TAC - SONIC TRAVEL TIME (MICROSECONDS/FOOT)
C     TACM - SONIC TRAVEL TIME (MICROSECONDS/CENTIMETRE)
      INTEGER TITLE
      DIMENSION ILUN(5),IDCB(144),NAMEF(3),IBUFF(40),CD(50),
     A DENA(50),DPH(50),DPHM(52),IXDPH(10),IYCON(16),IYSON(16),
     B IYDEN(11),ITITLE(40),RD(50),TAC(50),TACM(50),TITLE(26),
     C ISIGN1(6),ISIGN2(7),GR(50),IXGR(11),PORNL(50),IYPORN(10),
     D IYNAPI(14)
      DATA IBUFF /40*2H  /,TITLE /26*2H  /,ITITLE /40*2H  /
      CALL RMPAR(ILUN)
      LX=ILUN
       WRITE(LX,101)
  101 FORMAT("ENTER SOURCE ROCK DATA FILE NAME")
      READ(LX,102) NAMEF
  102 FORMAT(3A2)
      CALL OPEN(IDCB,IERR,NAMEF)
      IF(IERR.GE.0) GO TO 105
  103 WRITE(LX,104) IERR
  104 FORMAT("IERR= ",I4)
      GO TO 51
  105 CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,106)(TITLE(J),J=1,20)
  106 FORMAT(20A2)
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,107)(TITLE(J),J=21,26)
  107 FORMAT(6A2)
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
```

```
      READ(IBUFF,*)NSP,ICDL,IPL,MDPH,MTAC,NLTYPE,NPLOT
      DO 300 I=1,NSP
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      IF(ICDL.EQ.0) GO TO 108
      CALL CODE
      READ(IBUFF,*) DPH(I),GR(I),CD(I),DENA(I),TAC(I),PORNL(I)
      GO TO 300
  108 CALL CODE
      READ(IBUFF,*) DPH(I),GR(I),RD(I),DENA(I),TAC(I),PORNL(I)
  300 CONTINUE
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,*) IEND
   51 CALL CLOSE(IDCB,IERR)
      IF(IEND.NE.-1) STOP 1
C     THE FOLLOWING CONVERTS OIL FIELD UNITS TO METRIC & VICE-VERSA
      DO 301 I=1,NSP
      IF(MDPH.EQ.1) DPHM(I)=DPH(I)
      IF(MDPH.EQ.1) DPH(I)=DPH(I)/0.3048
      IF(MDPH.EQ.0) DPHM(I)=DPH(I)*0.3048
      IF(MTAC.EQ.1) TAC(I)=TAC(I)*30.48
      TACM(I)=TAC(I)/30.48
      IF(ICDL.EQ.0) CD(I)=1000.0/RD(I)
      IF(ICDL.EQ.1) RD(I)=1000.0/CD(I)
  301 CONTINUE
      WRITE(6,201)(TITLE(J),J=1,26)
  201 FORMAT(1H1,2/,50X,"CONFIDENTIAL",/,50X,12("-"),/,
     A 40X,20A2,22X,2A2,5X,4A2,2/)
      WRITE(6,202)
  202 FORMAT(5X,"SAMPLE",4X,"DEPTH",10X,"GAMMA RAY",3X,
     1 "RESISTIVITY",1X,
     A "CONDUCTIVITY",4X,"DENSITY",4X,"SONIC TRAVEL",10X,"NEUTRON",/,
     B 5X,"NUMBER",3X,"(MBRT)(FT.BRT)",1X,"(API UNITS)",2X,
     C "(OHM-METRE)",1X,
     D "(MILLIMHOS/M)",3X,"(GM/CC)",5X,"TIME",17X,"POROSITY",/,80X,
     E"(MUSEC/CM)(MUSEC/FT)",3X,"INDEX")
      DO 302 I=1,NSP
      WRITE(6,203)I,DPHM(I),DPH(I),GR(I),RD(I),CD(I),DENA(I),TACM(I),
     A TAC(I),PORNL(I)
  203 FORMAT(6X,I2,6X,F6.1,"(",F6.0,")",4X,F4.0,6X,F6.1,7X,F6.0,10X,
     A F4.2,7X,F4.2,7X,"(",F4.0,")",1X,F8.3)
  302 CONTINUE
C     PLOTTING OF DATA FOLLOWS
      IF(IPL.EQ.0) GO TO 111
      IF(NPLOT.EQ.2) GO TO 555
      CALL PLOTS(51.8,10.0,0,-1.0,-1.0)
  557 CALL PLOT(7.5,1.0,-3)
      CALL CODE
      WRITE(ISIGN1,400)
  400 FORMAT("SOURCE ROCK")
      CALL SYMB(2.0,1.0,0.6,ISIGN1,90.0,11)
```

```
      CALL CODE
      WRITE (ISIGN2,399)
  399 FORMAT("POTENTIAL LOG")
      CALL SYMB(3.6,1.0,0.6,ISIGN2,90.0,13)
      CALL PLOT(17.1,0.0,-3)
      CALL SCALE(DPHM(1),7.0,NSP,-1,DPHM(NSP+1),DPHM(NSP+2))
      CALL CODE
      WRITE(IXDPH,401)
  401 FORMAT("DEPTH (METRES)")
      CALL AXIS(0.0,0.0,IXDPH,14,7.0,180.0,DPHM(NSP+1),DPHM(NSP+2))
      CALL CODE
      WRITE(IYCON,402)
  402 FORMAT(" LOG CONDUCTIVITY (MILLIMHOS/M)")
      CALL AXIS(0.0,0.0,IYCON,-31,8.0,90.0,0.0,0.5)
      DO 303 I=1,NSP
      X=(DPHM(NSP+1)-DPHM(I))/(DPHM(NSP+2))
      Y=ALOG(CD(I))/2.3025851
      Y=(Y)/0.5
      IF(Y.LT.0.0) STOP11
      ANUMB=FLOAT(I)
C     PLOT OF LOG CONDUCTIVITY VERSUS DEPTH
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
  303 CONTINUE
      CALL CODE
      WRITE(ITITLE,403)(TIT E(J),J=1,26)
  403 FORMAT(20A2,10X,2A2,2X,4A2)
      CALL SYMB(-12.0,1.0,0.1,ITITLE,90.0,64)
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(8.5,0.0,-3)
      CALL CODE
      WRITE(IYSON,404)
  404 FORMAT("LOG SHALE TRAVEL TIME (MUSEC/CM)")
      CALL AXIS(0.0,0.0,IXDPH,14,7.0,180.0,DPHM(NSP+1),DPHM(NSP+2))
      CALL AXIS(0.0,0.0,IYSON,-32,8.0,90.0,0.1,0.1)
      DO 304 I=1,NSP
      X=(DPHM(NSP+1)-DPHM(I))/(DPHM(NSP+2))
      Y=ALOG(TACM(I))/2.3025851
      Y=(Y-0.1)/0.1
      IF(Y.LT.0.0) STOP12
      ANUMB=FLOAT(I)
C     PLOT OF LOG SONIC TRAVEL TIME VERSUS DEPTH
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
  304 CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(8.5,0.0,-3)
      CALL CODE
      WRITE(IYDEN,405)
  405 FORMAT("SHALE DENSITY (GM/CC)")
      CALL AXIS(0.0,0.0,IXDPH,14,7.0,180.0,DPHM(NSP+1),DPHM(NSP+2))
      CALL AXIS(0.0,0.0,IYDEN,-21,8.0,90.0,2.8,-0.1)
      DO 305 I=1,NSP
      IF(DENA(I).LE.1.9) GO TO 305
      X=(DPHM(NSP+1)-DPHM(I))/(DPHM(NSP+2))
      Y=(2.8-DENA(I))/0.1
      IF(Y.LT.0.0) STOP13
```

```
      ANUMB=FLOAT(I)
C     PLOT OF DENSITY VERSUS DEPTH
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
  305 CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(8.5,0.0,-3)
      IF(NLTYPE.EQ.1) GO TO 500
      CALL CODE
       WRITE(IYPORN,406)
  406 FORMAT("LOG NEUTRON POROSITY")
      CALL AXIS(0.0,0.0,IYPORN,-20,8.0,90.0,-2.0,0.25)
      GO TO 501
  500 CALL CODE
      WRITE(IYNAPI 407)
  407 FORMAT("NEUTRON POROSITY (API UNITS)")
      CALL AXIS(0.0,0.0,IYNAPI,-28,8.0,90.0,3000.0,-400.0)
  501 CALL AXIS(0.0,0.0,IXDPH,14,7.0,180.0,DPHM(NSP+1),DPHM(NSP+2))
      IF(NLTYPE.EQ.0) GO TO 310
       DO 310 I=1,NSP
      IF(PORNL(I).LE.0.01) GO TO 310
      X=(DPHM(NSP+1)-DPHM(I))/(DPHM(NSP+2))
      Y=ALOG(PORNL(I))/2.3025851
      Y=(Y+2.0)/0.25
       IF(NLTYPE.EQ.1) Y=-(PORNL(I)-3000.0)/400.0
      IF(Y.LT.0.0) STOP14
      ANUMB=FLOAT(I)
C     PLOT OF NEUTRON VERSUS DEPTH
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
  310 CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(0.0,0.0,999)
      CALL GOPLT
      IF(NPLOT.EQ.1) GO TO 111
  555 CALL XPLOT(IYSON,IYCON,TACM,CD,ITITLE,IYDEN,DENA,NLTYPE,
     A IYPORN,IYNAPI,PORNL,GR,TITLE,NPLOT,NSP)
  111 WRITE(LX,109)
  109 FORMAT("PROGRAM SRPL COMPLETED")
      STOP2
      END
      SUBROUTINE XPLOT(IYSON,IYCON,TACM,CD,ITITLE,IYDEN,DENA,NLTYPE,
     A IYPORN,IYNAPI,PORNL,GR,TITLE,NPLOT,NSP)
      INTEGER TITLE
      DIMENSION IYSON(16),IYCON(16),TACM(50),CD(50),ITITLE(40),
     A IYDEN(11),DENA(50),IYPORN(10),IYNAPI(14),PORNL(50),
     B GR(50),IXGR(11),TITLE(26),IDATI(2)
      CALL PLOTS(43.5,10.0,0,-1.0,-1.0)
      CALL PLOT(8.2,1.0,-3)
      CALL CODE
      WRITE(IYCON,402)
  402 FORMAT(" LOG CONDUCTIVITY (MILLIMHOS/M)")
      CALL CODE
      WRITE(ITITLE,403)(TITLE(J),J=1,26)
  403 FORMAT(20A2,10X,2A2,2X,4A2)
      CALL CODE
      WRITE(IYSON,404)
```

```
  404 FORMAT("LOG SHALE TRAVEL TIME (MUSEC/CM)")
      CALL CODE
      WRITE(IYDEN,405)
  405 FORMAT("SHALE DENSITY (GM/CC)")
      CALL CODE
       WRITE(IYPORN,406)
  406 FORMAT("LOG NEUTRON POROSITY")
  500 CALL CODE
      WRITE(IYNAPI,407)
  407 FORMAT("NEUTRON POROSITY (API UNITS)")
      CALL AXIS(0.0,0.0,IYSON,32,7.0,180.0,0.1,0.10)
      CALL AXIS(0.0,0.0,IYCON,-31,8.0,90.0,0.0,0.5)
      DO 306 I=1,NSP
      X=ALOG(TACM(I))/2.3025851
      X=-(X-0.1)/0.1
      Y=ALOG(CD(I))/2.3025851
      Y=(Y)/0.5
      IF(Y.LT.0.0) STOP21
      ANUMB=FLOAT(I)
C     PLOT OF LOG SONIC TRAVEL TIME VERSUS LOG CONDUCTIVITY
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
  306 CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(8.55,0.0,-3)
      CALL AXIS(0.0,0.0,IYDEN,21,7.0,180.0,2.8,-0.1)
      CALL AXIS(0.0,0.0,IYCON,-31,8.0,90.0,0.0,0.5)
      DO 307 I=1,NSP
      IF(DENA(I).LE.1.9) GO TO 307
      X=-(2.8-DENA(I))/0.1
      Y=ALOG(CD(I))/2.3025851
      Y=(Y)/0.5
      IF(Y.LT.0.0) STOP22
      ANUMB=FLOAT(I)
C     PLOT OF DENSITY VERSUS LOG CONDUCTIVITY
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
  307 CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
  562 CALL CODE
      WRITE (IXGR,408)
  408 FORMAT("GAMMA RAY (API UNITS)")
      CALL PLOT(8.5,0.0,-3)
      CALL AXIS(0.0 ,0.0,IYSON,32,7.0,180.0,0.1,0.10)
      CALL AXIS(0.0,0.0,IXGR,-21,8.0,90.0,20.0,20.0)
      DO 308 I=1,NSP
      IF(GR(I).LE.20.0)  GO TO 308
      X=ALOG(TACM(I))/2.3025851
      X=-(X-0.1)/0.1
      Y=(GR(I)-20.0)/20.0
      IF(Y.LT.0.0) STOP23
      ANUMB=FLOAT(I)
C     PLOT OF GAMMA RAY VERSUS LOG SONIC TRAVEL TIME
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
  308 CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(8.55,0.0,-3)
```

```
      CALL AXIS(0.0,0.0,IYDEN,21,7.0,180.0,2.8,-0.1)
      IF(NLTYPE.EQ.1) GO TO 311
      CALL AXIS(0.0,0.0,IYPORN,-20,8.0,90.0,-2.0,0.25)
      GO TO 312
  311 CALL AXIS(0.0,0.0,IYNAPI,-28,8.0,90.0,3000.0,-400.0)
  312 DO 313 I=1,NSP
      IF(NLTYPE.EQ.0) GO TO 313
      IF(DENA(I).LE.1.9) GO TO 313
      IF(PORNL(I).LE.0.01) GO TO 313
      X=-(2.8-DENA(I))/0.1
      Y=ALOG(PORNL(I))/2.3025851
      Y=(Y+2.0)/0.25
      IF(NLTYPE.EQ.1) Y=-(PORNL(I)-3000.0)/400.0
      IF(Y.LT.0.0) STOP24
      ANUMB=FLOAT(I)
C     CROSSPLOT OF NEUTRON VERSUS DENSITY
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
  313 CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
  888 CALL PLOT(0.0,0.0,999)
      CALL GOPLT
      RETURN
      END
      SUBROUTINE BLANK(IBUFF)
C     THIS SUBROUTINE CLEARS ARRAY "IBUFF" BETWEEN READ STATEMENTS
      DIMENSION IBUFF(40)
      DO 100 I=1,40
      IBUFF(I)=2H
  100 CONTINUE
      RETURN
      END
      END$
```

```
FTN4,B
      PROGRAM SRPL
C     SOURCE ROCK POTENTIAL LOG PROGRAM
C     PREPARED BY L.E.KURYLOWICZ--DEC.1977
C     ---------------LIST OF PARAMETERS------------------
C     CD - CONDUCTIVITY (MILLIMHOS/METRE)
C     DENA - DENSITY (GM/CC)
C     DPH - DEPTH (FT BELOW RT)
C     DPHM - DEPTH (METRES BELOW RT)
C     GR - GAMMA RAY READING (API UNITS)
C     ICDL - CONDUCTIVITY READINGS SWITCH (1=YES;0=NO)
C     IPL - PLOT SWITCH (1=YES;0=NO)
C     MDPH - METRIC DEPTH SWITCH (1=YES;0=NO)
C     MTAC - METRIC SONIC READINGS SWITCH (1=YES;0=NO)
C     NAMEF - SOURCE ROCK DATA FILE NAME
C     NLTYPE - NEUTRON LOG TYPE(0-NONE;1-API UNITS;2-SNP OR CNL)
C     NPLOT- NUMBER OF PLOTS(1:Y VS. DEPTH; 2:X-PLOTS)
C     RD - DEEP RESISTIVITY READINGS (OHM-METRE)
C     TAC - SONIC TRAVEL TIME (MICROSECONDS/FOOT)
C     TACM - SONIC TRAVEL TIME (MICROSECONDS/CENTIMETRE)
      INTEGER TITLE
      DIMENSION ILUN(5),IDCB(144),NAMEF(3),IBUFF(40),CD(50),
     A DENA(50),DPH(50),DPHM(52),IXDPH(10),IYCON(16),IYSON(16),
     B IYDEN(11),ITITLE(40),RD(50),TAC(50),TACM(50),TITLE(26),
     C ISIGN1(6),ISIGN2(7),GR(50),IXGR(11),PORNL(50),IYPORN(10),
     D IYNAPI(14)
      DATA IBUFF /40*2H  /,TITLE /26*2H  /,ITITLE /40*2H  /
      CALL RMPAR(ILUN)
      LX=ILUN
       WRITE(LX,101)
 101  FORMAT("ENTER SOURCE ROCK DATA FILE NAME")
      READ(LX,102) NAMEF
 102  FORMAT(3A2)
      CALL OPEN(IDCB,IERR,NAMEF)
      IF(IERR.GE.0) GO TO 105
 103  WRITE(LX,104) IERR
 104  FORMAT("IERR= ",I4)
      GO TO 51
 105  CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,106)(TITLE(J),J=1,20)
 106  FORMAT(20A2)
```

```
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,107)(TITLE(J),J=21,26)
107   FORMAT(6A2)
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,*)NSP,ICDL,IPL,MDPH,MTAC,NLTYPE,NPLOT
      DO 300 I=1,NSP
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      IF(ICDL.EQ.0) GO TO 108
      CALL CODE
      READ(IBUFF,*) DPH(I),GR(I),CD(I),DENA(I),TAC(I),PORNL(I)
      GO TO 300
108   CALL CODE
      READ(IBUFF,*) DPH(I),GR(I),RD(I),DENA(I),TAC(I),PORNL(I)
300   CONTINUE
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,*) IEND
51    CALL CLOSE(IDCB,IERR)
      IF(IEND.NE.-1) STOP 1
C     THE FOLLOWING CONVERTS OIL FIELD UNITS TO METRIC & VICE-VERSA
      DO 301 I=1,NSP
      IF(MDPH.EQ.1) DPHM(I)=DPH(I)
      IF(MDPH.EQ.1) DPH(I)=DPH(I)/0.3048
      IF(MDPH.EQ.0) DPHM(I)=DPH(I)*0.3048
      IF(MTAC.EQ.1) TAC(I)=TAC(I)*30.48
      TACM(I)=TAC(I)/30.48
      IF(ICDL.EQ.0) CD(I)=1000.0/RD(I)
      IF(ICDL.EQ.1) RD(I)=1000.0/CD(I)
301   CONTINUE
      WRITE(6,201)(TITLE(J),J=1,26)
201   FORMAT(1H1,2/,50X,"CONFIDENTIAL",/,50X,12("-"),/,
     A 40X,20A2,22X,2A2,5X,4A2,2/)
      WRITE(6,202)
202   FORMAT(5X,"SAMPLE",4X,"DEPTH",10X,"GAMMA RAY",3X,
```

```
     1 "RESISTIVITY",1X,
     A "CONDUCTIVITY",4X,"DENSITY",4X,"SONIC TRAVEL",10X,"NEUTRON",/,
     B 5X,"NUMBER",3X,"(MBRT)(FT.BRT)",1X,"(API UNITS)",2X,
     C "(OHM-METRE)",1X,
     D "(MILLIMHOS/M)",3X,"(GM/CC)",5X,"TIME",17X,"POROSITY",/,80X,
     E"(MUSEC/CM)(MUSEC/FT)",3X,"INDEX")
      DO 302 I=1,NSP
      WRITE(6,203)I,DPHM(I),DPH(I),GR(I),RD(I),CD(I),DENA(I),TACM(I),
     A TAC(I),PORNL(I)
 203  FORMAT(6X,I2,6X,F6.1,"(",F6.0,")",4X,F4.0,6X,F6.1,7X,F6.0,10X,
     A F4.2,7X,F4.2,7X,"(",F4.0,")",1X,F8.3)
 302  CONTINUE
C     PLOTTING OF DATA FOLLOWS
      IF(IPL.EQ.0) GO TO 111
      IF(NPLOT.EQ.2) GO TO 555
      CALL PLOTS(51.8,10.0,0,-1.0,-1.0)
 557  CALL PLOT(7.5,1.0,-3)
      CALL CODE
      WRITE(ISIGN1,400)
 400  FORMAT("SOURCE ROCK")
      CALL SYMB(2.0,1.0,0.6,ISIGN1,90.0,11)
      CALL CODE
      WRITE (ISIGN2,399)
 399  FORMAT("POTENTIAL LOG")
      CALL SYMB(3.6,1.0,0.6,ISIGN2,90.0,13)
      CALL PLOT(17.1,0.0,-3)
      CALL SCALE(DPHM(1),7.0,NSP,-1,DPHM(NSP+1),DPHM(NSP+2))
      CALL CODE
      WRITE(IXDPH,401)
 401  FORMAT("DEPTH (METRES)")
      CALL AXIS(0.0,0.0,IXDPH,14,7.0,180.0,DPHM(NSP+1),DPHM(NSP+2))
      CALL CODE
      WRITE(IYCON,402)
 402  FORMAT(" LOG CONDUCTIVITY (MILLIMHOS/M)")
      CALL AXIS(0.0,0.0,IYCON,-31,8.0,90.0,0.0,0.5)
      DO 303 I=1,NSP
      X=(DPHM(NSP+1)-DPHM(I))/(DPHM(NSP+2))
      Y=ALOG(CD(I))/2.3025851
      Y=(Y)/0.5
      IF(Y.LT.0.0) STOP11
      ANUMB=FLOAT(I)
C     PLOT OF LOG CONDUCTIVITY VERSUS DEPTH
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
 303  CONTINUE
```

```
      CALL CODE
      WRITE(ITITLE,403)(TITLE(J),J=1,26)
 403  FORMAT(20A2,10X,2A2,2X,4A2)
      CALL SYMB(-12.0,1.0,0.1,ITITLE,90.0,64)
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(8.5,0.0,-3)
      CALL CODE
      WRITE(IYSON,404)
 404  FORMAT("LOG SHALE TRAVEL TIME (MUSEC/CM)")
      CALL AXIS(0.0,0.0,IXDPH,14,7.0,180.0,DPHM(NSP+1),DPHM(NSP+2))
      CALL AXIS(0.0,0.0,IYSON,-32,8.0,90.0,0.1,0.1)
      DO 304 I=1,NSP
      X=(DPHM(NSP+1)-DPHM(I))/(DPHM(NSP+2))
      Y=ALOG(TACM(I))/2.3025851
      Y=(Y-0.1)/0.1
      IF(Y.LT.0.0) STOP12
      ANUMB=FLOAT(I)
C     PLOT OF LOG SONIC TRAVEL TIME VERSUS DEPTH
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
 304  CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(8.5,0.0,-3)
      CALL CODE
      WRITE(IYDEN,405)
 405  FORMAT("SHALE DENSITY (GM/CC)")
      CALL AXIS(0.0,0.0,IXDPH,14,7.0,180.0,DPHM(NSP+1),DPHM(NSP+2))
      CALL AXIS(0.0,0.0,IYDEN,-21,8.0,90.0,2.8,-0.1)
      DO 305 I=1,NSP
      IF(DENA(I).LE.1.9) GO TO 305
      X=(DPHM(NSP+1)-DPHM(I))/(DPHM(NSP+2))
      Y=(2.8-DENA(I))/0.1
      IF(Y.LT.0.0) STOP13
      ANUMB=FLOAT(I)
C     PLOT OF DENSITY VERSUS DEPTH
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
 305  CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(8.5,0.0,-3)
      IF(NLTYPE.EQ.1) GO TO 500
      CALL CODE
       WRITE(IYPORN,406)
 406  FORMAT("LOG NEUTRON POROSITY")
      CALL AXIS(0.0,0.0,IYPORN,-20,8.0,90.0,-2.0,0.25)
      GO TO 501
```

```
 500  CALL CODE
      WRITE(IYNAPI,407)
 407  FORMAT("NEUTRON POROSITY (API UNITS)")
      CALL AXIS(0.0,0.0,IYNAPI,-28,8.0,90.0,3000.0,-400.0)
 501  CALL AXIS(0.0,0.0,IXDPH,14,7.0,180.0,DPHM(NSP+1),DPHM(NSP+2))
      IF(NLTYPE.EQ.0) GO TO 310
       DO 310 I=1,NSP
      IF(PORNL(I).LE.0.01) GO TO 310
      X=(DPHM(NSP+1)-DPHM(I))/(DPHM(NSP+2))
      Y=ALOG(PORNL(I))/2.3025851
      Y=(Y+2.0)/0.25
       IF(NLTYPE.EQ.1) Y=-(PORNL(I)-3000.0)/400.0
      IF(Y.LT.0.0) STOP14
      ANUMB=FLOAT(I)
C     PLOT OF NEUTRON VERSUS DEPTH
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
 310  CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(0.0,0.0,999)
      CALL GOPLT
      IF(NPLOT.EQ.1) GO TO 111
 555  CALL XPLOT(IYSON,IYCON,TACM,CD,ITITLE,IYDEN,DENA,NLTYPE,
     A IYPORN,IYNAPI,PORNL,GR,TITLE,NPLOT,NSP)
 111  WRITE(LX,109)
 109  FORMAT("PROGRAM SRPL COMPLETED")
      STOP2
      END
      SUBROUTINE XPLOT(IYSON,IYCON,TACM,CD,ITITLE,IYDEN,DENA,NLTYPE,
     A IYPORN,IYNAPI,PORNL,GR,TITLE,NPLOT,NSP)
      INTEGER TITLE
      DIMENSION IYSON(16),IYCON(16),TACM(50),CD(50),ITITLE(40),
     A IYDEN(11),DENA(50),IYPORN(10),IYNAPI(14),PORNL(50),
     B GR(50),IXGR(11),TITLE(26),IDATI(2)
      CALL PLOTS(43.5,10.0,0,-1.0,-1.0)
      CALL PLOT(8.2,1.0,-3)
      CALL CODE
      WRITE(IYCON,402)
 402  FORMAT(" LOG CONDUCTIVITY (MILLIMHOS/M)")
      CALL CODE
      WRITE(ITITLE,403)(TITLE(J),J=1,26)
 403  FORMAT(20A2,10X,2A2,2X,4A2)
      CALL CODE
      WRITE(IYSON,404)
 404  FORMAT("LOG SHALE TRAVEL TIME (MUSEC/CM)")
```

```
      CALL CODE
      WRITE(IYDEN,405)
 405  FORMAT("SHALE DENSITY (GM/CC)")
      CALL CODE
       WRITE(IYPORN,406)
 406  FORMAT("LOG NEUTRON POROSITY")
 500  CALL CODE
      WRITE(IYNAPI,407)
 407  FORMAT("NEUTRON POROSITY (API UNITS)")
      CALL AXIS(0.0,0.0,IYSON,32,7.0,180.0,0.1,0.10)
      CALL AXIS(0.0,0.0,IYCON,-31,8.0,90.0,0.0,0.5)
      DO 306 I=1,NSP
      X=ALOG(TACM(I))/2.3025851
      X=-(X-0.1)/0.1
      Y=ALOG(CD(I))/2.3025851
      Y=(Y)/0.5
      IF(Y.LT.0.0) STOP21
      ANUMB=FLOAT(I)
C     PLOT OF LOG SONIC TRAVEL TIME VERSUS LOG CONDUCTIVITY
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
 306  CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(8.55,0.0,-3)
      CALL AXIS(0.0,0.0,IYDEN,21,7.0,180.0,2.8,-0.1)
      CALL AXIS(0.0,0.0,IYCON,-31,8.0,90.0,0.0,0.5)
      DO 307 I=1,NSP
      IF(DENA(I).LE.1.9) GO TO 307
      X=-(2.8-DENA(I))/0.1
      Y=ALOG(CD(I))/2.3025851
      Y=(Y)/0.5
      IF(Y.LT.0.0) STOP22
      ANUMB=FLOAT(I)
C     PLOT OF DENSITY VERSUS LOG CONDUCTIVITY
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
 307  CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
 562  CALL CODE
      WRITE (IXGR,408)
 408  FORMAT("GAMMA RAY (API UNITS)")
      CALL PLOT(8.5,0.0,-3)
      CALL AXIS(0.0 ,0.0,IYSON,32,7.0,180.0,0.1,0.10)
      CALL AXIS(0.0,0.0,IXGR,-21,8.0,90.0,20.0,20.0)
      DO 308 I=1,NSP
      IF(GR(I).LE.20.0)  GO TO 308
```

```
      X=ALOG(TACM(I))/2.3025851
      X=-(X-0.1)/0.1
      Y=(GR(I)-20.0)/20.0
      IF(Y.LT.0.0) STOP23
      ANUMB=FLOAT(I)
C     PLOT OF GAMMA RAY VERSUS LOG SONIC TRAVEL TIME
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
 308  CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
      CALL PLOT(8.55,0.0,-3)
      CALL AXIS(0.0,0.0,IYDEN,21,7.0,180.0,2.8,-0.1)
      IF(NLTYPE.EQ.1) GO TO 311
      CALL AXIS(0.0,0.0,IYPORN,-20,8.0,90.0,-2.0,0.25)
      GO TO 312
 311  CALL AXIS(0.0,0.0,IYNAPI,-28,8.0,90.0,3000.0,-400.0)
 312  DO 313 I=1,NSP
      IF(NLTYPE.EQ.0) GO TO 313
      IF(DENA(I).LE.1.9) GO TO 313
      IF(PORNL(I).LE.0.01) GO TO 313
      X=-(2.8-DENA(I))/0.1
      Y=ALOG(PORNL(I))/2.3025851
      Y=(Y+2.0)/0.25
      IF(NLTYPE.EQ.1) Y=-(PORNL(I)-3000.0)/400.0
      IF(Y.LT.0.0) STOP24
      ANUMB=FLOAT(I)
C     CROSSPLOT OF NEUTRON VERSUS DENSITY
      CALL NUMB(X,Y,0.07,ANUMB,90.0,0,0.07,1)
 313  CONTINUE
      CALL SYMB(-7.0,1.0,0.1,ITITLE,90.0,64)
 888  CALL PLOT(0.0,0.0,999)
      CALL GOPLT
      RETURN
      END
      SUBROUTINE BLANK(IBUFF)
C     THIS SUBROUTINE CLEARS ARRAY "IBUFF" BETWEEN READ STATEMENTS
      DIMENSION IBUFF(40)
      DO 100 I=1,40
      IBUFF(I)=2H
 100  CONTINUE
      RETURN
      END
      END$
```