Late Tertiary to Early Pleistocene in age.

The conglomerate in the F formation is mainly pebble in size accompanied by cobbles and boulders and has sandy matrix. The pebbles are not so clustered and a regularity in their arrangement can be recognized. In addition, the size and density of the pebbles represents a marked stratification. With respect to the sort and ratio of the constituting pebbles, gabbro is most abundant, followed by basalt, andesite and sandstone in addition to limestone, quartzite and chert. Occasionally, the conglomerate intercalates sandstone layers with a thickness of 0.5 to 6 m. This sandstone is well-sorted and fine-grained and with well-developed lamina. The conglomerate and the sandstone intercalate calcareous bands which pebble and sand are cemented by calcareous materials with a thickness of several to several tens cm, and these bands emphasizes its stratified appearance. Although in the east of the hill muddy bed is likely to be intercalated in below the conglomerate, the details are not yet clear because of its poor exposure.

Judging from lithofacies and distribution, the F formation corresponds to the Iday Formation studied by CORBY et al. (1951) and SANTOS (1968) identified the age of the Iday Formation as the Pliocene, but recently it is considered to fall in the Early Pleistocene (ex., HASHIMOTO, 1981).

3) Sedimentary facies and sedimentary history

As described previously, the Tertiary of this area starts with volcanic formation consisting mainly of andesite and basalt, followed by reefal limestone and then a thick sequence of mudstone and sandstone with occasional interbeds of pebbly mudstone and conglomerate.

Mudstone and sandstone alternate in beds of less than 10 cm thick in most case. Medium to thick alternation of them also occurs at some horizons within the C and E formations.

In the alternation of sandstone and mudstone graded bedding develops remarkably and a change in grain size from lower sandstone to upper mudstone is gradual in many cases (Pl. 5, fig. 1). The base of the sandstone is sharp and in thinner layer parallel lamina develops well. In the top part of it ripple cross-lamination is observed very often. Sandstone forming the medium to thick alternation is generally medium-grained or sometimes coarse-grained accompanying conglomerate. The sandstone, which is usually massive, shows distinct graded bedding, and at the base erosional plane can be observed in many cases. In addition, the sandstone includes abundant

fragments of shell and coral and also contains calcareous nodule frequently. Meanwhile, in rare cases the C_2 member and the E_1 member have ripple mark and cross-bedding in the sandstones (Pl. 5, fig. 2), respectively.

In the bottom part and on the upper surface of the sandstones in the thin alternations such trace fossils as *Taphrhelminthopsis* (Pl. 6, fig. 2) and *Buthotrephis*-like burrow (Pl. 6, fig. 3) are found. These type of trace fossils can be seen in flysh, and so the presence of them indicates bathyal environment. The mudstones are mostly silty, and have rarely mega fossils.

The Tertiary system in the survey area consisting mainly of alternation of sandstone and mudstone shows the turbidite characteristics, while shell and coral fossils yielded in crowds in the E_2 member came with coarse-grained sediments from the shallow sea in the periphery of the depositional basin. The basin, which is assumed to extend almost south-north, is likely to have remarkably steep slopes. This is indicated by the development of slump deposits including pebbly mudstone and the presence of ill-sorted conglomerate containing intrabasinal pebbles formed by contemporaneous erosion at some horizons, as well as by inflow of outer neritic fossils as mentioned above (Pl. 6, fig. 1).

On the whole, the sedimentary basin seems to have been deepened rapidly after deposition of the B_1 member (limestone bed), and to have kept the greatest depth during the stage of the D_3 member, followed by a gradual shallowing. Although there are a few data on the paleocurrents, southward currents are recognized. The Tertiary sediments within the survey area may have been supplied from the western mountainous area.

4. Exploratory drillings

In the southern part of the Iloilo basin, nine exploratory drillings of oil in total with the total length of 17,479 m have been drilled, as shown in Text-fig. 4-1. Of these nine wells in Oton-1 and Mandurriao-1 indications of oil were detected. Although shows of gas were detected in all of the wells, they were judged to be not commercial, so that those wells were plugged and abandoned. Those estimations seem to be based on a viewpoint as structural gas, but not as kyosui-sei-gasu.

The data of those wells, which are pigeonholed and kept very well in the Library and Data Bank of the Bureau of Energy Development along with the records of the seismic surveys carried out over the southern part of the Iloilo basin, was very helpful to this investigation.

1) Geology and logging

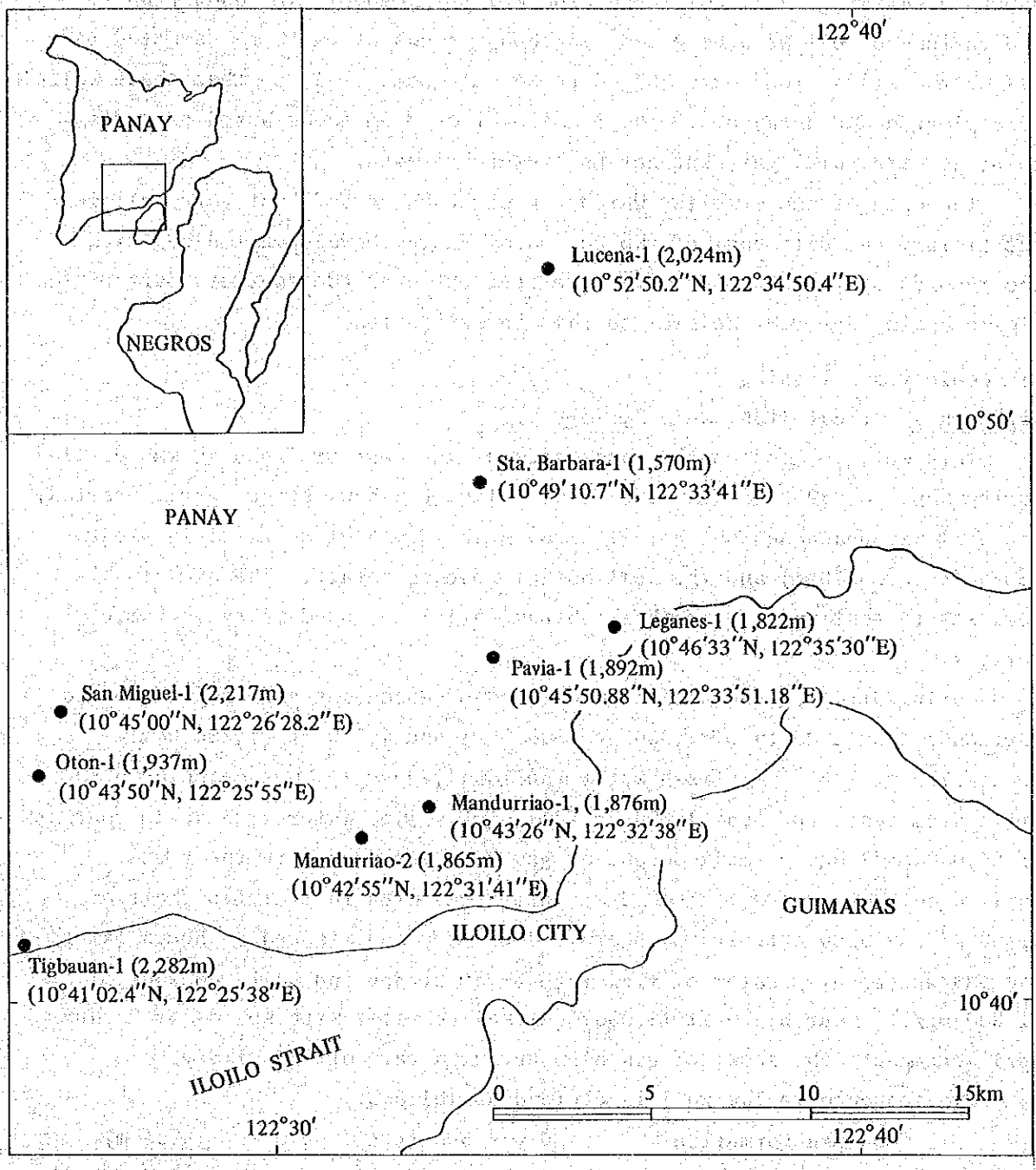
Tigbauan-1 (Text-figs. 4-1, 2, 13)

This well located on the coast side of the east of Tigbauan was drilled during Sep. 16, 1959 to Jan. 11, 1960. Although shows of gas were detected, the well was abandoned on Jan. 11, 1960. The depth of the well is about 7,485 ft (2,282.0 m) and the well bottom reaches basalt. The aim of this well was to test the top of the Tigbauan Anticline found by the seismic surveys.

During drilling the well blew out and produced gas and water from two horizons, near a depth of 1,300 ft (396.3 m) and 4,100 ft (1,250.0 m). Near 1,250 ft (381.1 m) fresh water (solids 7,700 mg/l) was detected by a drill stem test, and near 1,350 ft (411.6 m) saline water with solid content of 24,000 mg/l and a small amount of gas were recorded. In the test carried out near 2,100 ft (640.2 m), after gas with initial flow rate of 9,200 m^3/day blew out, it was sharply decreased and stopped 48 hours later. The gas accompanied water of flow rate of 40 kl/day and solid content of 31,000 mg/l. Near 3,400 ft (1,036.6 m) saline water with solids of 27,400 mg/l accompanied by shows of gas blew out at a rate of 240 kl/day.

The sequence in the well is divided as follows:

Cabatuan Formation	0 - 500 ft	(0 - 152.4 m)
Iday Group	500 - 2,700 ft	(152.4 - 823.2 m)
Panoran Formation	2,700 - 3,400 ft	(823.3 - 1,036.6 m)
Dingle Limestone	3,400 - 3,950 ft	(1,036.6 - 1,204.3 m)
Tarao-Singit Group	3,950 - 5,450 ft	(1,204.3 - 1,661.6 m)
Antalon Group	5,450 - 6,254 ft	(1,661.6 - 1,906.7 m)
Basement volcanics	6,254 - 7,485 ft	(1,906.7 - 2,282.0 m)



TEXT-FIGURE 4-1

Location map of exploratory drillings in the southern part of Iloilo basin.

(Logging)

In this well electric logging was conducted for a depth interval of 89 to 7,476 ft (27 to 2,280 m) (Text-fig. 4-2). Resistivity in the section shallower than 3,350 ft (1,020 m) ranges from 0.75 to 2.7 Ωm. The peaks at a depth of 1,350 ft (411 m), 1,700 ft (518 m) and 2,100 ft (640 m) correspond to sandstones. The section of high resistivity shallower than 600 ft (183 m) is assumed to indicate invasion of meteoric water. In the section between 3,350 and 5,400 ft depth (1,020 to 1,650 m) several peaks are found. The peaks at 3,450 ft (1,050 m) and 3,800 ft (1,160 m) and those at 4,300 ft (1,310 m), 4,400 ft (1,340 m) and 4,550 ft (1,390 m) correspond to limestones and sandstones, respectively. The section of high resistivity (5 - 60 Ωm) at a depth deeper than 5,600 ft (1,710 m) corresponds to basalt.

Oton-1 (Text-figs. 4-1, 13)

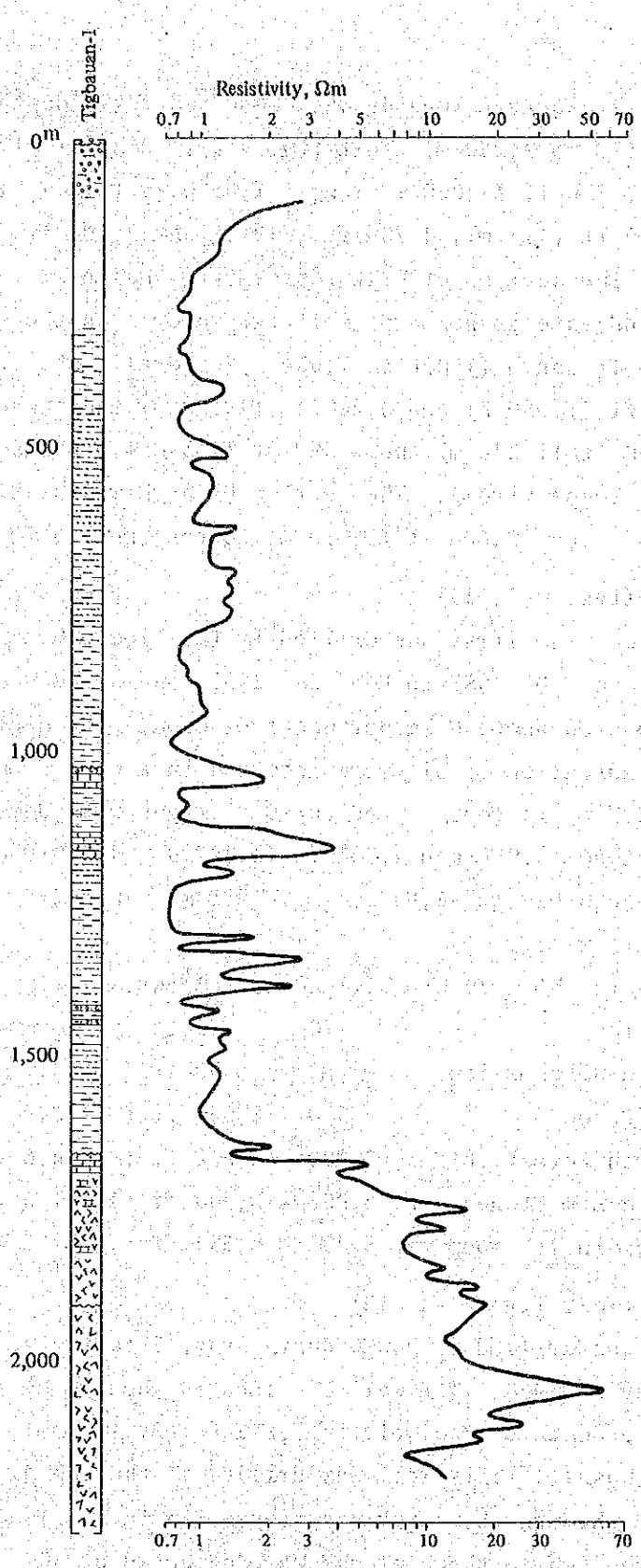
This well was the first one drilled in the Iloilo basin. It was drilled by PDJV during Jan. 20, 1953 to Feb. 25, 1953, and abandoned on Mar. 2. The well was located about 6 km northwest of Oton. The depth is 6,354 ft (1,937.2 m). Indication of oil were detected in a core sample of shale at 4,555 ft (1,388.7 m) in depth. Indications of gas were detected in the core samples between 3,926 and 4,231 ft (1,197.0 - 1,290.0 m) and in those between 6,009 and 6,019 ft (1,832.0 - 1,835.1 m). Electric logging has not conducted in this well.

The strata in the well are divided as follows.

Alluvium	0 - 50 ft	(0 - 15.2 m)
Cabatuan Formation	50 - 500 ft	(15.2 - 152.4 m)
Iday Group	500 - 3,000 ft	(152.4 - 914.6 m)
Panoran Formation	3,000 - 4,958 ft	(914.6 - 1,511.6 m)
Dingle Limestone	4,958 - 5,700 ft	(1,511.6 - 1,737.8 m)
Tarao-Singit Group	5,700 - 6,354 ft	(1,737.8 - 1,937.2 m)

San Miguel-1 (Text-figs. 4-1, 13)

This well was drilled by PODCO during Mar. 3 to May 2, 1960, and abandoned on May 2, 1960. The well was located about 4 km southwest of San Miguel. The depth of the well is 7,272 ft (2,217.1 m). The well bottom reaches basalt. This well was drilled at the top of the San Miguel Anticline found through the seismic surveys. In the well any shows of oil were not detected, while shows of gas were detected at 500 - 507 ft (152.4 - 154.6 m) and 6,170 - 6,175 ft (1,881.1 - 1,882.6 m) in depth.



TEXT-FIGURE 4-2

Resistivity in Tigbauan-1.

The strata of the well are divided as follows:

Cabatuan Formation	0 - 510 ft	(0 - 155.5 m)
Iday Group	510 - 2,780 ft	(155.5 - 847.6 m)
Panoran Formation	2,780 - 4,900 ft	(847.6 - 1,493.9 m)
Dingle Limestone	4,900 - 5,650 ft	(1,493.9 - 1,722.6 m)
Tarao-Singit Group	5,650 - 6,900 ft	(1,722.6 - 2,103.7 m)
Antalon Group	6,900 - 7,170 ft	(2,103.7 - 2,186.0 m)
Basement volcanics	7,170 - 7,272 ft	(2,186.0 - 2,217.1 m)

Mandurriao-1 (Text-figs. 4-1, 3, 4, 13)

This well was drilled to the east of Mandurriao during Apr. 30 to Jun. 2, 1973, by PODCO, and abandoned on Jun. 2, 1973. The depth of the well is 6,153 ft (1,875.9 m) and the bottom reaches basalt. The aim of the well was to test the porous limestone of the Dingle Formation at the northern wing of the anticline running north to south found by the seismic surveys. According to the seismic profiles, a buildup structure considered to be reefal limestone is observed at this drilling site.

The top of the well up to a depth of 1,440 ft (439.0 m) consists of sand and shale of the Pleistocene, and near 300 ft (91.5 m) shows of methane was detected.

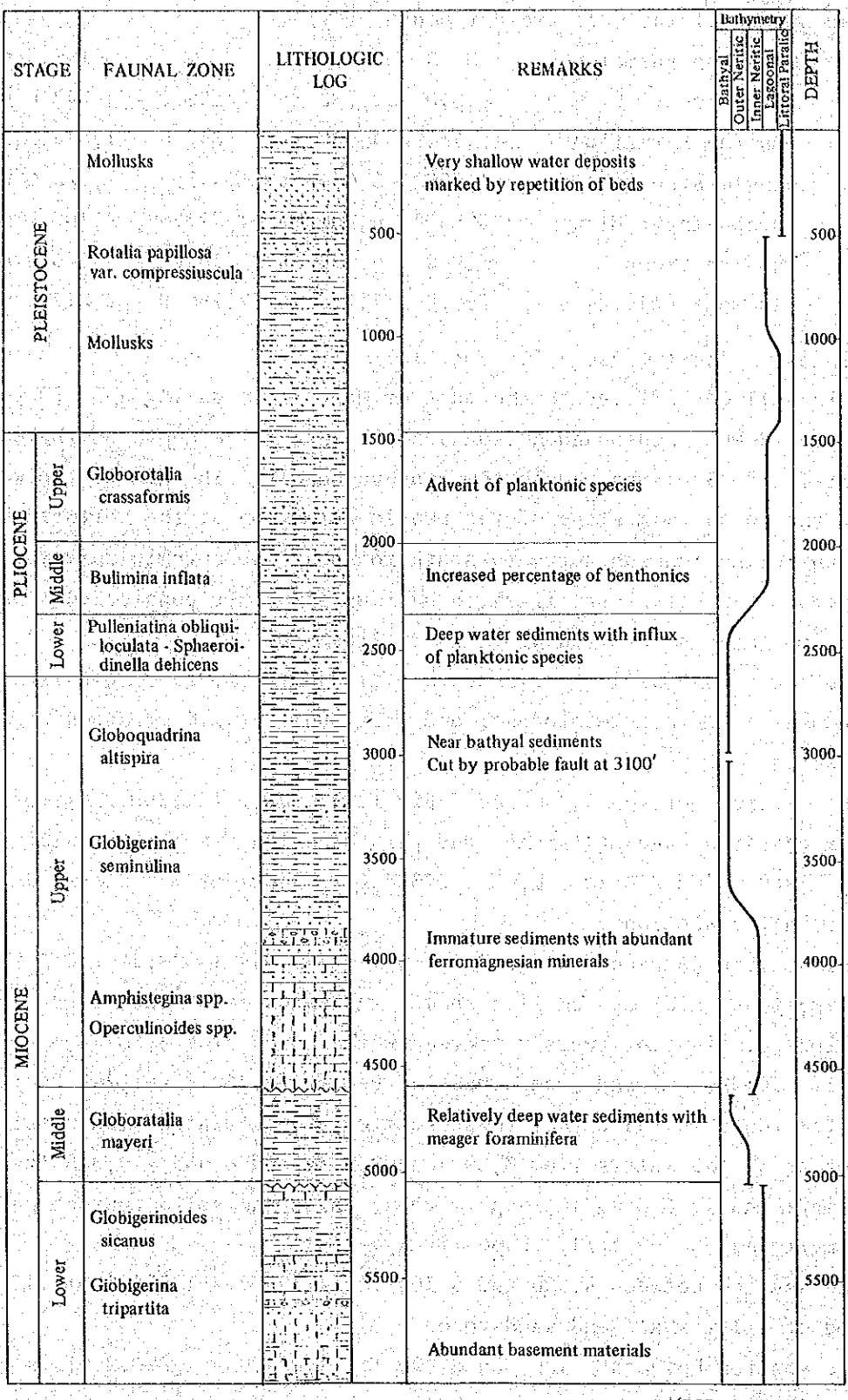
The section between 1,440 and 3,860 ft (1,176.8 - 1,390.2 m) consists of of thick claystone and siltstone, and thin sandstones are intercalated between 1,980 and 2,210 ft (603.7 - 673.8 m). Shows of methane were detected in the section.

The section between 3,860 and 4,560 ft (439.0 - 1,390.2 m) consists of thick limestone intercalated with shales and sands, and shows of gas and indications of light oil were detected in the cores from 3,897 - 3,933 ft (1,188.1 - 1,199.1 m) and from 4,065 - 4,096 ft (1,239.3 - 1,248.8 m). Drill stem tests revealed that these section are saturated with water. The Cl^- content of the waters from 3,897 - 3,933 ft and 4,065 - 4,096 ft were 20,800 mg/l and 17,600 mg/l, respectively, while the solid content was 38,500 mg/l and 30,700 mg/l, respectively.

The section between 4,560 and 5,100 ft (1,390.2 - 1,554.9 m) is composed of silty shale and sandstone.

The section between 5,100 and 5,990 ft (1,554.9 - 1,826.2 m) is formed of limestone with silty and sandy shales.

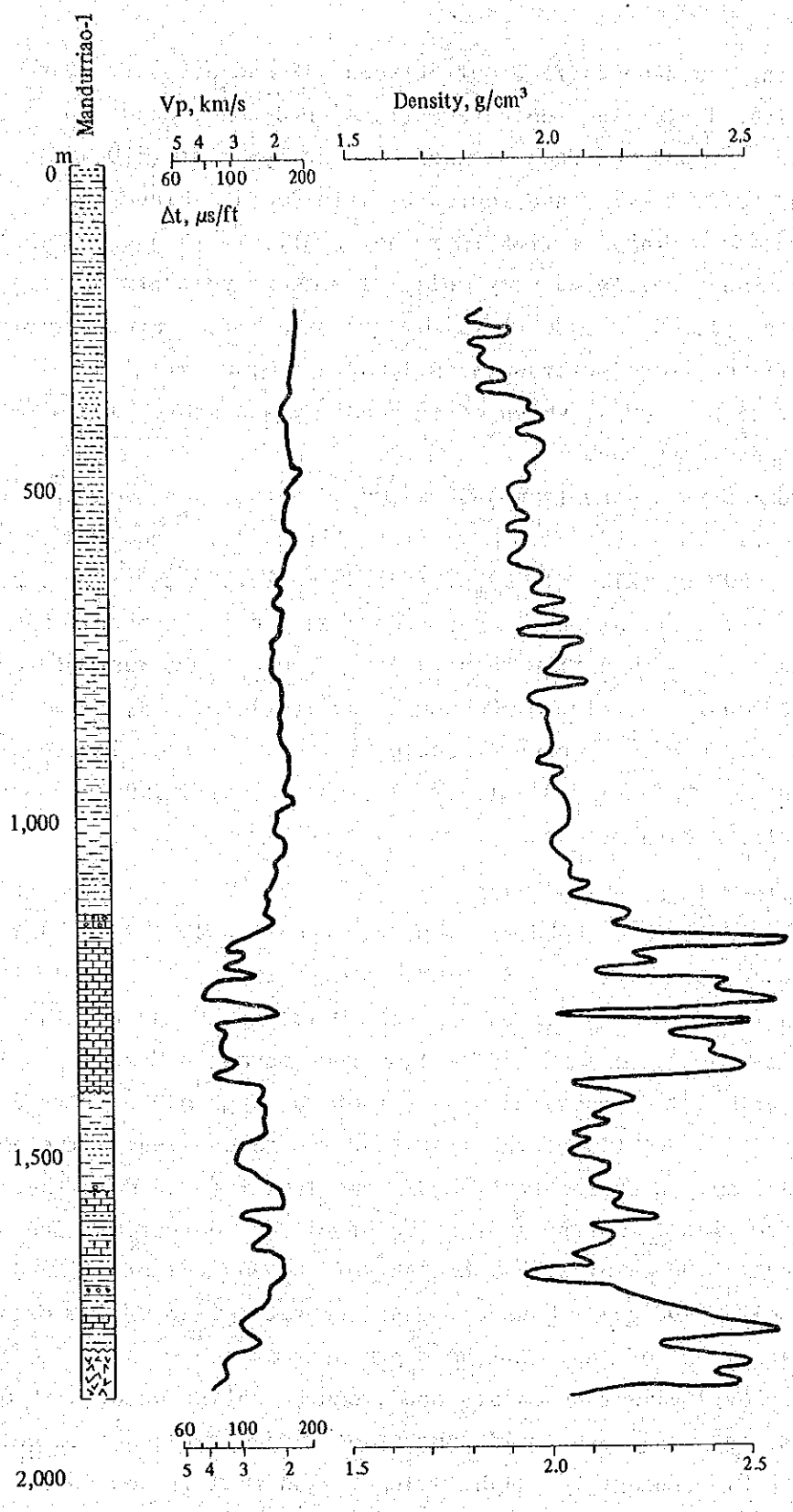
The section from 5,990 ft (1,826.2 m) to the bottom of 6,153 ft (1,875.9 m) is weathered basalt.



(PODCO, 1973b)

TEXT-FIGURE 4-3

Lithology, micropaleontology and bathymetry of Mandurriao-1.



TEXT-FIGURE 4-4

Sonic velocity and density in Mandurriao-1.

(Logging)

Sonic logging has been carried out between 718 and 6,136 ft (219 - 1,870 m) (Text-fig. 4-4). The sonic velocity of mudstone, sandstone and alternating sandstone and mudstone between 718 and 3,800 ft (219 - 1,160 m) ranges from 1.69 to 2.18 km/s, and increases with depth. Since sonic velocity fluctuation of this section is rather small, it is assumed that sandstone has not been developed very well. The sonic velocity between 3,800 and 4,600 ft (1,160 - 1,400 m) is 2.77 to 4.35 km/s, which corresponds to limestone. The sonic velocity between 4,600 and 5,600 ft (1,400 - 1,710 m) is 1.97 to 3.05 km/s, which corresponds to sandstone, and alternating mudstone and limestone.

Formation density logging (gamma-gamma ray logging) has been conducted between 718 and 6,147 ft (219 - 1,870 m) (Text-fig. 4-4). The density between 718 and 3,800 ft (219 - 1,160 m) is 1.85 to 2.15 g/cm^3, increasing with depth. Density fluctuation is observed to some extent above 2,650 ft (808 m), and the parts with a high density are assumed to correspond to sandstones. The density between 3,800 and 4,600 ft (1,160 - 1,400 m) ranges from 2.2 to 2.6 g/cm^3, which corresponds to limestone. The density between 4,600 and 5,600 ft (1,400 - 1,710 m) with a density 1.9 to 2.3 g/cm^3 corresponds to alternating sandstone, mudstone and limestone.

Mandurriao-2 (Text-figs. 4-1, 5, 13)

This well was drilled by PODCO in Mandurriao during Jun. 23 to Jul. 22, 1974, and abandoned on Jul. 23, 1974. The depth of the well is 6,118 ft (1,860 m) and the well bottom reaches basalt. Drilling of the well aimed at testing the indications of oil in reefal limestone found in Mandurriao-1 drilled 1.7 km northeast of the well at a structural high place exposed on the seismic profiles. The top of the limestone was recognized at the depth of 3,756 ft (1,145 m), which was confirmed to be 100 ft (30.5 m) higher than that of Mandurriao-1, but no indication of oil was detected. The limestone yielded saline water with a content of 16,300 mg/l of Cl^- and 94,000 mg/l of solids and gas. However, gas flow rate could not be measured owing to a little amount of gas. At the depth between 3,010 and 3,620 ft (920 - 1,070 m) reefal limestone exists and produced saline water with Cl^- content of 16,940 mg/l and with solid content of 43,340 mg/l. It is worthy of note that this Cl^- content is slightly lower than that in sea water (19,200 mg/l).

(Stratigraphy)

o Pleistocene 0 - 1,210 ft (0 - 369.0 m)

Mainly consisting of unconsolidated sands and gravels intercalated with silts and sands. Shell fragments are contained.

o Pliocene 1,210 - 2,790 ft (369.0 - 850.6 m)

This section was divided from the upper section according to a faunal change in the Late Pliocene. On the electric logs, no lithological change is recognized near the boundary between this section and the lower one.

In this section shales intercalating thin beds of siltstones and limestones are dominant. The shales are green to gray in color, limy with abundant fossils, partly silty and tuffaceous. The interval between 2,450 and 2,520 ft (747.0 - 768.3 m) consists of brown to white limestones containing fossils such as corals. The shales deeper than 2,760 ft (841.5 m) are very calcareous. Near the boundary with the lower section at the depth of 2,790 ft (850.6 m), no lithological change is recognized on the electric logs.

o Upper Miocene 2,790 - 4,575 ft (850.6 - 1,394.8 m)

The upper part of this section consists of green colored limy shale and marly shale, and is partly silty. At 3,018 ft (920.1 m) the lithofacies changes suddenly to limestone. The upper part of the limestone is reefal rubble, and the main part consists of reefal limestone, continuing up to 3,620 ft (1,103.7 m). The limestone is white to creamy and abundant in fossils. The interval between 3,620 and 3,757 ft (1,103.7 - 1,145.4 m) is composed of shales and silts containing abundant fossils. From 3,757 ft (1,145.4 m) the section becomes white reefal rubble again, and under the rubble changes into reefal limestone. The limestone which continues to 4,450 ft (1,356.7 m) is creamy to white with abundant fossils, hard and dense, but has some intergranular and coralline porosities. The interval between 4,450 and 4,575 ft (1,356.7 - 1,394.8 m) consists of siltstone, shale and a few thin beds of dense limestone.

o Middle Miocene

In this well being lack.

o Lower Miocene 4,575 - 5,165 ft (1,394.8 - 1,574.7 m)

Between this section and that of the Upper Miocene, no discernable lithological change is recognized on the electric logs. This section is characterized by sandstone in the upper part and limestone, siltstone and shale in the lower part.

o Oligocene 5,165 - 6,050 ft (1,574.7 - 1,844.5 m)

The upper part of this section consists of several beds of siltstones

and green colored shales intercalated with limestones, and the middle part is composed of marly shale. At 5,740 ft (1,750 m) it changes into hard, dense, white, pyritic limestone and continues to 6,050 ft (1,844.5 m).

o Basement complex 6,050 - 6,118 ft (1,844.5 - 1,865.2 m)

The cuttings from 6,050 ft (1,844.5 m) contain an amount of hornblende and pyroxene crystals. In the cuttings from 6,090 ft (1,856.7 m) limestones coexist. Since in the core samples from the interval between 6,090 and 6,119 ft (1,856.7 - 1,865.2 m) chloritized dark green basalt was found, it was judged to be from true basement.

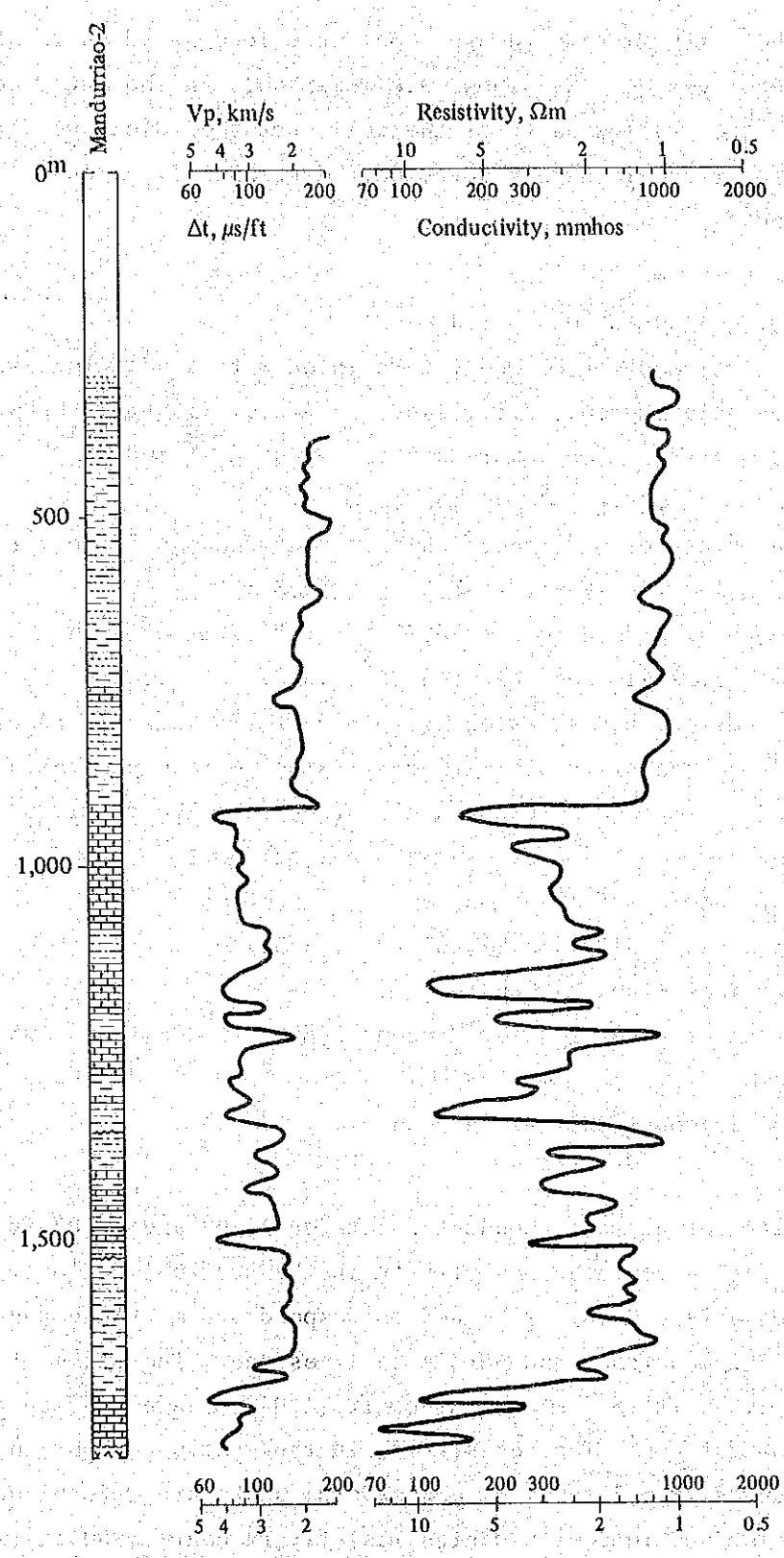
(Logging)

Sonic logging has been conducted between 925 and 6,070 ft (282 -1,850 m) (Text-fig. 4-5). The sonic velocity of mudstone, sandstone and alternating sandstone and mudstone between 925 and 3,000 ft (282 - 914 m) is 1.81 to 2.06 km/s, and shows an increasing tendency with depth. At a depth of 1,250 ft (381 m), 1,650 ft (503 m), 2,000 ft (610 m) and 3,000 ft (914 m) low sonic velocity layers exist and at 2,500 ft (762 m) a high sonic layer exists. The former and the latter correspond to mudstones and limestone, respectively. The sonic velocity between 3,000 and 6,070 ft (914 - 1,850 m) ranges from 2.10 to 4.69 km/s, and the layers higher than 3.0 km/s and the layers lower than 3.0 km/s correspond to limestones, and sandstones and mudstones, respectively.

Electric logging has been conducted between 925 and 6,079 ft (282 - 1,850 m) (Text-fig. 4-5). The resistivity between 925 and 3,000 ft (282 - 914 m) is 700 to 1,100 mmhos, decreases with depth. The low resistivity part at a depth of 2,500 ft (762 m) corresponds to limestone. The resistivity between 3,000 and 6,079 ft (914 - 1,850 m) is 70 to 920 mmhos, and the parts less than 400 mmhos correspond to limestones and the parts more than 400 mmhos correspond to sandstones and mudstones. The pyritic limestone distributed below the depth of 5,470 ft (1,670 m) has low resistivity as 70 mmhos.

Pavia-1 (Text-figs. 4-1, 6, 7, 13)

This well was drilled by PODCO during Apr. 27 to May 10, 1980, and abandoned on May 10, 1980. The drilling site is located about 3 km southeast of Pavia and the depth is 6,205 ft (1,891.8 m). The drilling was stopped in the limestone of the Uppermost Oligocene or the Lowermost Miocene. The purpose of drilling the well was to survey the buildup structure of reefal



TEXT-FIGURE 4-5

Sonic velocity and conductivity in Mandurriao-2.

limestone of the Early Miocene in age. Gas were recognized in this well, but oil were not detected. Gas shows are remarkable in the interbedded sand and mud of the shallow parts of the well, but they decrease with depth and at the bottom they are hardly detected. Gas shows also tend to be weak in carbonate rocks.

(Stratigraphy)

o Pleistocene 0 - 1,100 ft (0 - 335.4 m)

The upper part consists of mud intercalated with sand. The middle is composed of intercalating mud, silt, sand and gravel with thin beds of calcarenite and micrite. The lower part is composed of mud.

o Pliocene 1,100 - 2,160 ft (335.4 - 658.5 m)

Consisting mainly of mudstone, and siltstone and shale are intercalated.

o Upper Miocene 2,160 - 4,770 ft (658.5 - 1,454.3 m)

Chiefly composed of mudstone to 3,220 ft (981.7 m) with thin beds of siltstone; mudstone, shale and calcarenite to 3,270 ft (1,134.1 m); intercalating sandstone and siltstone to 3,930 ft (1,198.2 m); intercalating sandstone, mudstone and siltstone with detrital limestone and reefal debris to 4,590 ft (1,399.4 m); sandstone and siltstone to 4,770 ft (1,454.3 m).

o Middle Miocene 4,770 - 5,450 ft (1,454.3 - 1,661.6 m)

Composed of inter-reefal carbonates.

o Lower Miocene 5,450 - 5,890 ft (1,661.6 - 1,795.7 m)

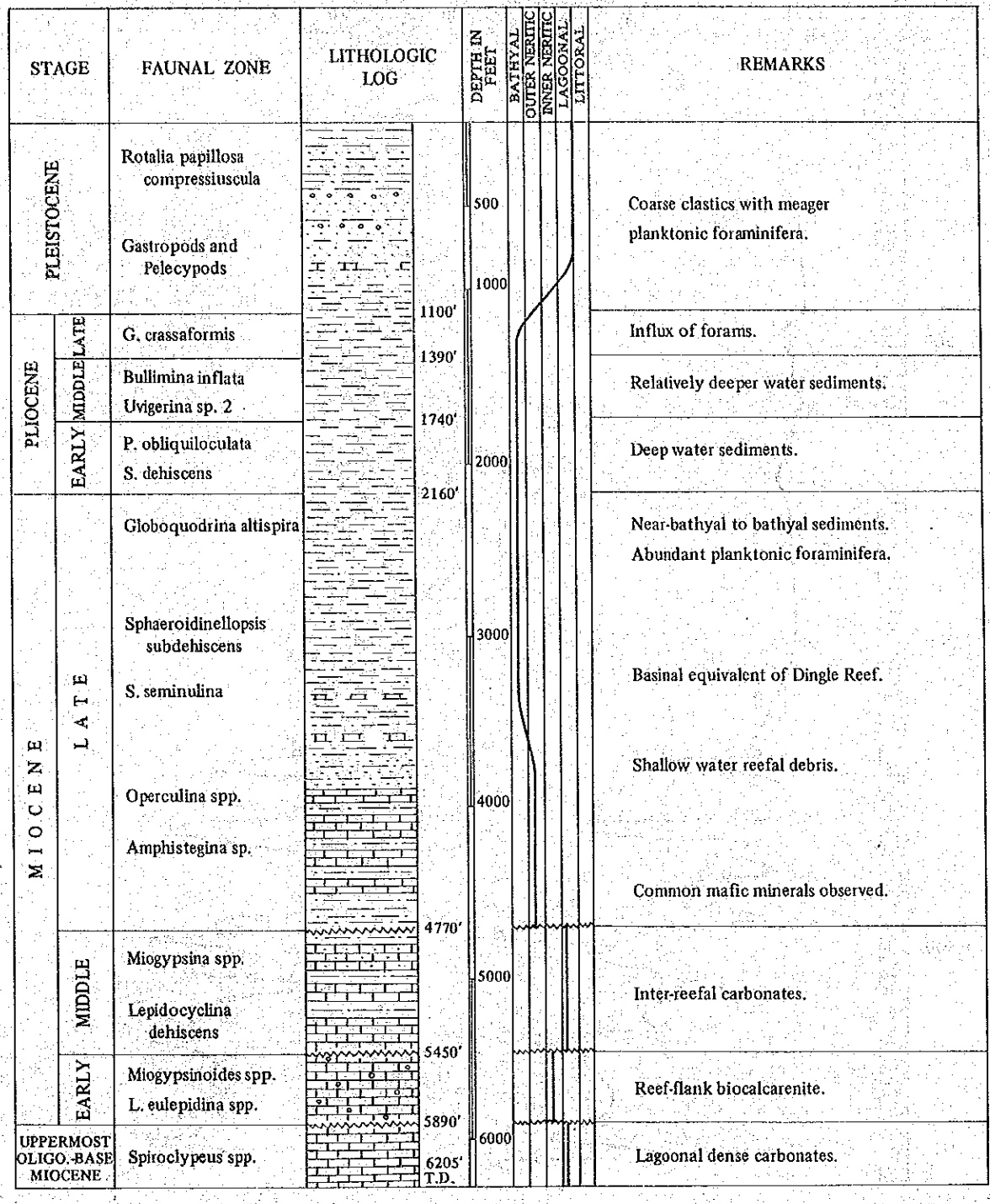
Composed of reef-flank carbonates.

o Uppermost Oligocene – Basal Lower Miocene 5,890 - 6,205 ft (1,796.7 - 1,891.8 m)

Composed of lagoonal/shelfal carbonates.

(Logging)

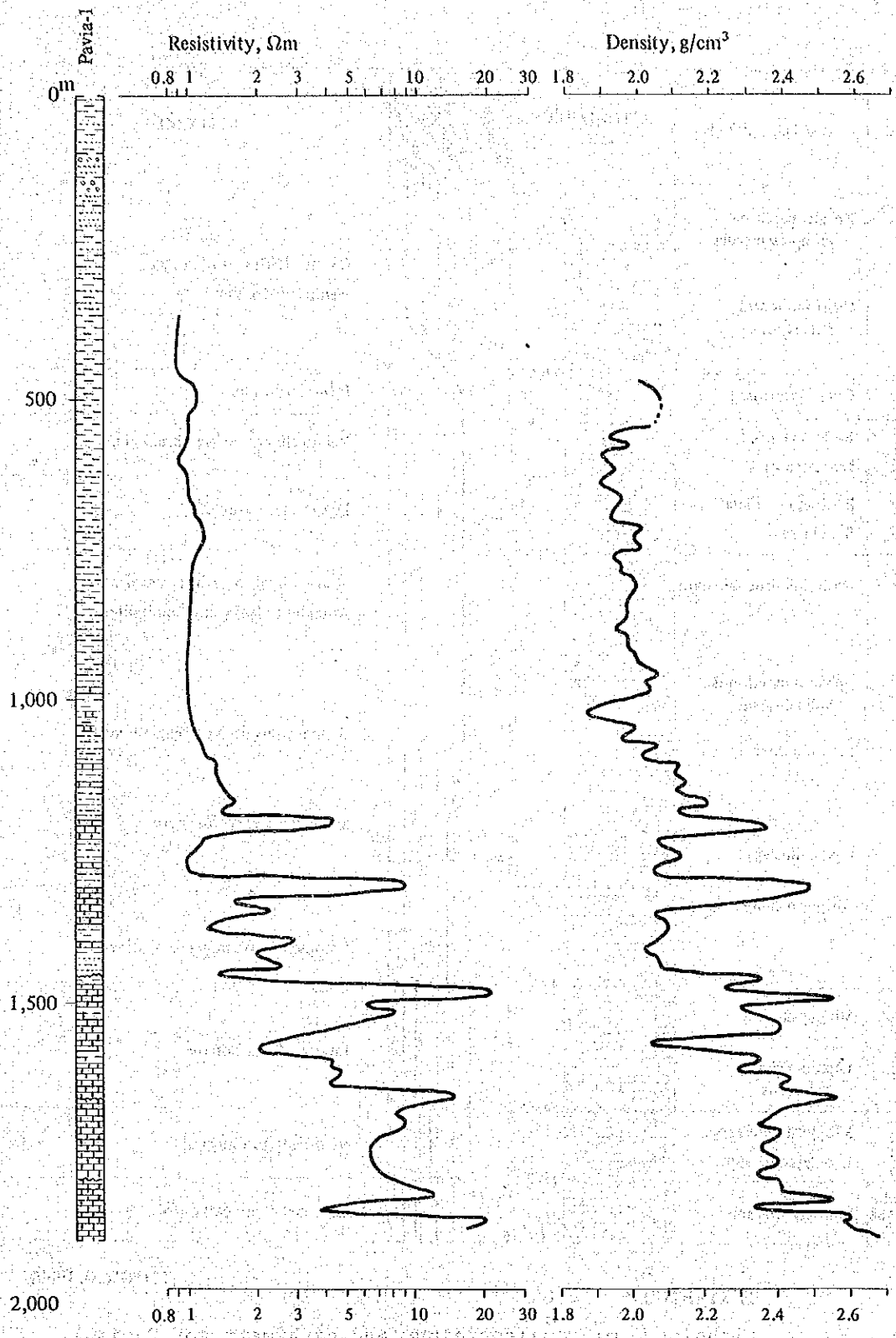
Electric logging has been conducted between 1,209 and 6,207 ft (369 - 1,890 m) (Text-fig. 4-7). The resistivity in the section shallower than 3,400 ft (1,040 m) is 0.9 to 1.2 Ωm and corresponds to mudstone and alternating sandstone and mudstone, and partly to limestone. The peaks of resistivity at 1,650 ft (503 m) and 3,400 ft (1,040 m) are assumed to correspond to sandstones. The resistivity in the section deeper than 3,400 ft (1,040 m) ranges from 1 to 24 Ωm and several peaks are recognized in this section. The sections with a high resistivity near 3,950 ft (1,200 m), 4,300 ft (1,310 m), 4,900 ft (1,490 m) and deeper than 3,400 ft (1,040 m) correspond to limestones. The invaded zone of meteoric water is assumed to be shallower than 1,200 ft (366 m).



(PODCO, 1980)

TEXT-FIGURE 4-6

Lithology, micropaleontology and bathymetry of Pavia-1.



TEXT-FIGURE 4-7

Resistivity and density in Pavia-1.

Formation density logging has been carried out between 1,211 ft and 6,208 ft (369 - 1,890 m) (Text-fig. 4-7). The density in the section shallower than 3,600 ft (1,100 m) is about 2.0 g/cm^3 and a little fluctuation is recognized. The sections near 1,650 ft (503 m) and 2,400 ft (731.7 m) with a high resistivity have also a high density. The density in the section deeper than 3,600 ft (1,100 m) increases with depth, and at 6,200 ft (1,890 m) it reaches 2.62 g/cm^3. The peaks at 4,000 ft (1,220 m), 4,300 ft (1,310 m) and 4,900 ft (1,490 m) coincide with the peaks of resistivity and correspond to limestones.

Leganes-1 (Text-figs. 4-1, 8, 13)

This well is located southeast of Leganes, about 1 km upcountry from the coast. It was drilled by PODCO during Sep. 14 to Oct. 2, 1974, but it was abandoned because of dry well. The drilling depth is 5,975 ft (1,821.6 m) and the bottom reaches basalt. Drilling the well aimed at investigating the Miocene reefal limestone assumed through seismic surveys.

The top part of this well to 920 ft (280.5 m) is consisted of the Pleistocene section, of which the upper 250 ft is gravelly and of which the lower part consists of gray siltstone and shale. The section between 920 and 1,295 ft (280.5 - 395.4 m) is formed of the Pliocene siltstone intercalated with shale. The section between 1,297 and 4,737 ft (395.4 - 1,444.2 m) belongs to the Upper Miocene and soft, grey shale continues from the upper section reaching reefal limestone at a depth of 2,638 ft (804.3 m). This reefal limestone with a high porosity continues to 3,310 ft (1,009.1 m) being saturated by water. The section between 3,310 and 3,610 ft (1,009.1 - 1,100.6 m) is composed of sandstone with limestone beds. The section between 3,610 and 4,240 ft (1,100.6 - 1,292.7 m) mainly consists of sandstone and that between 4,240 and 4,737 ft (1,292.7 - 1,444.3 m) is formed of shale, sandstone and limestone.

This well is lacking of the Middle Miocene. The Lower Miocene corresponds to the section between 4,737 and 5,867 ft (1,444.2 - 1,788.7 m) consisting of hard, dense limestone which has a fair-good porosity judging from logging. The section from 5,867 to 5,952 ft of the bottom (1,814.6 m) is formed of hornblende basalt.

In the occasion of testing limestone lying between 2,646 and 2,660 ft (806.7 - 811.0 m) gas was yielded with saline water, but it was impossible to measure because of too little volume.

(logging)

Sonic logging has been conducted between 880 and 5,980 ft (268 - 1,820 m) (Text-fig. 4-8). The sonic velocity of mudstone and alternating sandstone and mudstone shallower than 2,600 ft (792 m) ranges from 1.52 to 1.93 km/s. The sonic velocity increases sharply from a depth of 2,600 ft (792 m) the velocities at 2,900 - 3,300 ft (884 - 1,010 m), 4,200 ft (1,280 m), 5,000 ft (1,520 m) and the section deeper than 5,300 ft (1,620 m) reaches 4.0 km/s or more. These sections with a high sonic velocity correspond to dense, hard limestones, and the parts with a sonic velocity of 1.95 to 4.0 km/s correspond to sandstones, mudstones and limestones.

Formation density logging has been carried out between 881 and 5,968 ft (269 - 1,820 m) (Text-fig. 4-8). The density of the part shallower than 2,600 ft (792 m) ranges from 1.82 to 2.00g/cm^3, increasing with depth. The sections at 2,600 - 3,300 ft (792 - 1,010 m), 3,500 - 3,600 ft (1,070 - 1,100 m), 4,200 - 4,250 ft (1,280 - 1,300 m), 4,950 - 5,000 ft (1,510 - 1,520 m) and deeper than 5,250 ft (1,600 m) with a density of 2.28 - 2.97 g/cm^3 correspond to limestones. The low density parts with a density of 2.00 - 2.85 g/cm^3 lying among them correspond to sandstones and mudstones.

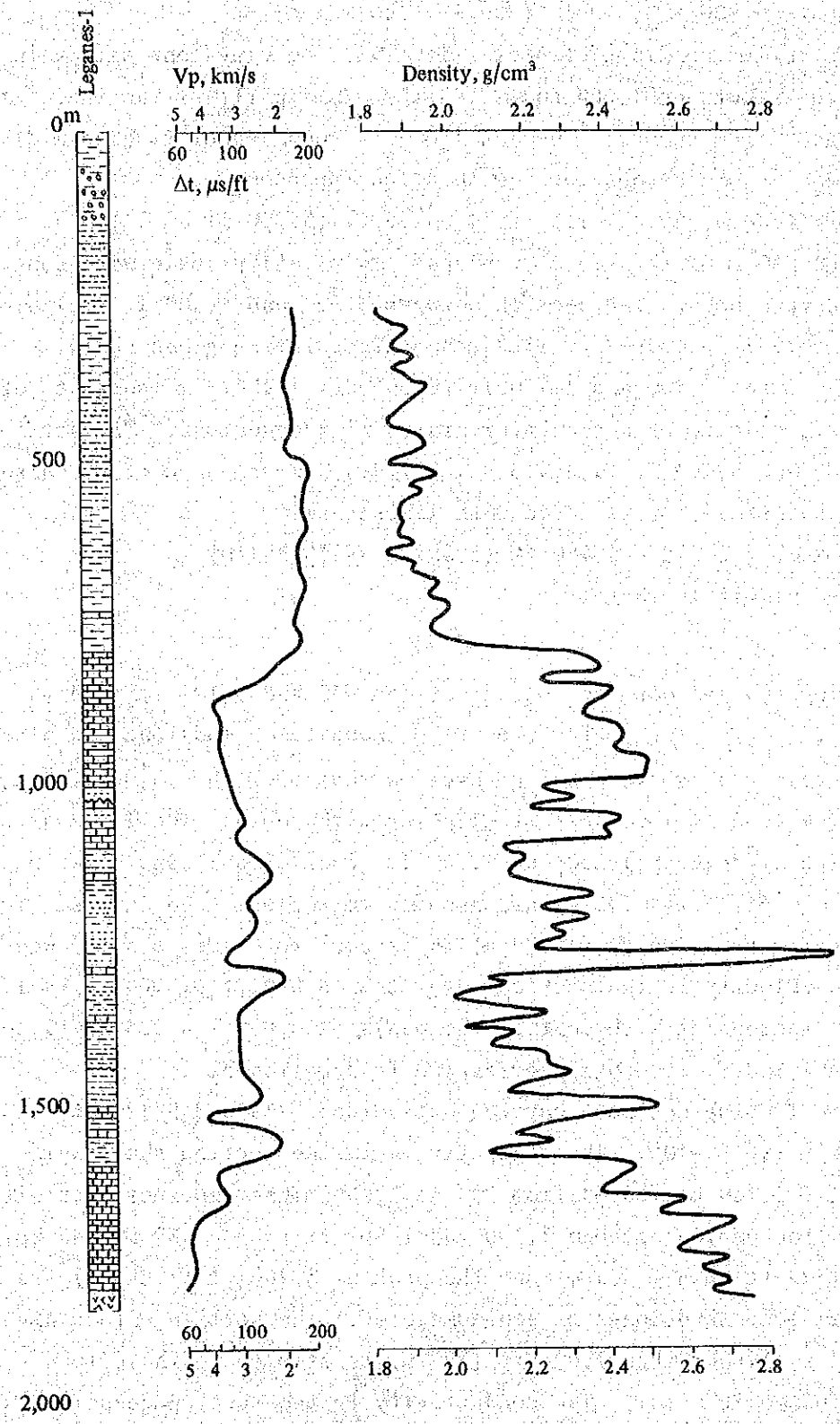
Sta. Barbara-1 (Text-figs. 4-1, 9, 10, 13)

This well was drilled by PODCO during Mar. 20 to Apr. 6, 1973, and abandoned on Apr. 6, 1973. The site is located 2.5 km east of Sta. Barbara and the drilling depth is 5,150 ft (1,570.1 m). The well bottom reaches basalt. This well is sited near the top of the anticlinal structure with NE-SW direction which was found through the seismic surveys, and was drilled for the purpose of examining the limestone and sandstone in the Dingle and Passi Formations. Although any indications of oil were not detected in this well, many shows of gas were detected between 500 and 2,600 ft (152.4 - 792.7 m). According to electric logs the reservoirs are filled with water and the salinities of the waters in a depth of 3,800 ft (1,158.5 m) and more range from 30,000 to 35,000 ppm.

(Stratigraphy)

o Cabatuan Formation 0 - 920 ft (0 - 280.5 m)

This formation occupying the upper part of the well mainly consists of silty shale intercalated with sandstone. The sandstone contains pebble in part. The lowest part of this formation is divided from the underlying Ulian Formation by frequent occurrence of shallow water megafossils which characterize this formation and of Pleistocene foraminifera.



TEXT-FIGURE 4-8

Sonic velocity and density of Leganes-1.

o Ulian Formation 920 - 3,450 ft (280.5 - 1,051.8 m)

This formation consists of gray silty shale or claystone with thin sandstone lenses between 1,300 and 2,100 ft. Some parts of the shale are calcareous and carbonaceous. The sandstone is composed of fine to medium-grained fragments of igneous rocks with a low roundness.

o Dingle Formation 3,450 - 5,110 ft (1,051.8 - 1,557.9 m)

The upper 50 m of this formation consists of silty shale with conglomeratic sandstone beds. The section between 3,860 and 4,100 ft (1,176.8 - 1,250 m) is chiefly composed of limestone intercalating green shale. The section between 4,100 and 4,770 ft (1,250.0 - 1,454.3 m) consists of greenish gray, calcareous shale intercalated with sandstone. The section between 4,770 and 5,110 ft (1,454.3 - 1,557.9 m) is composed of greenish gray calcareous shale intercalated with limestones.

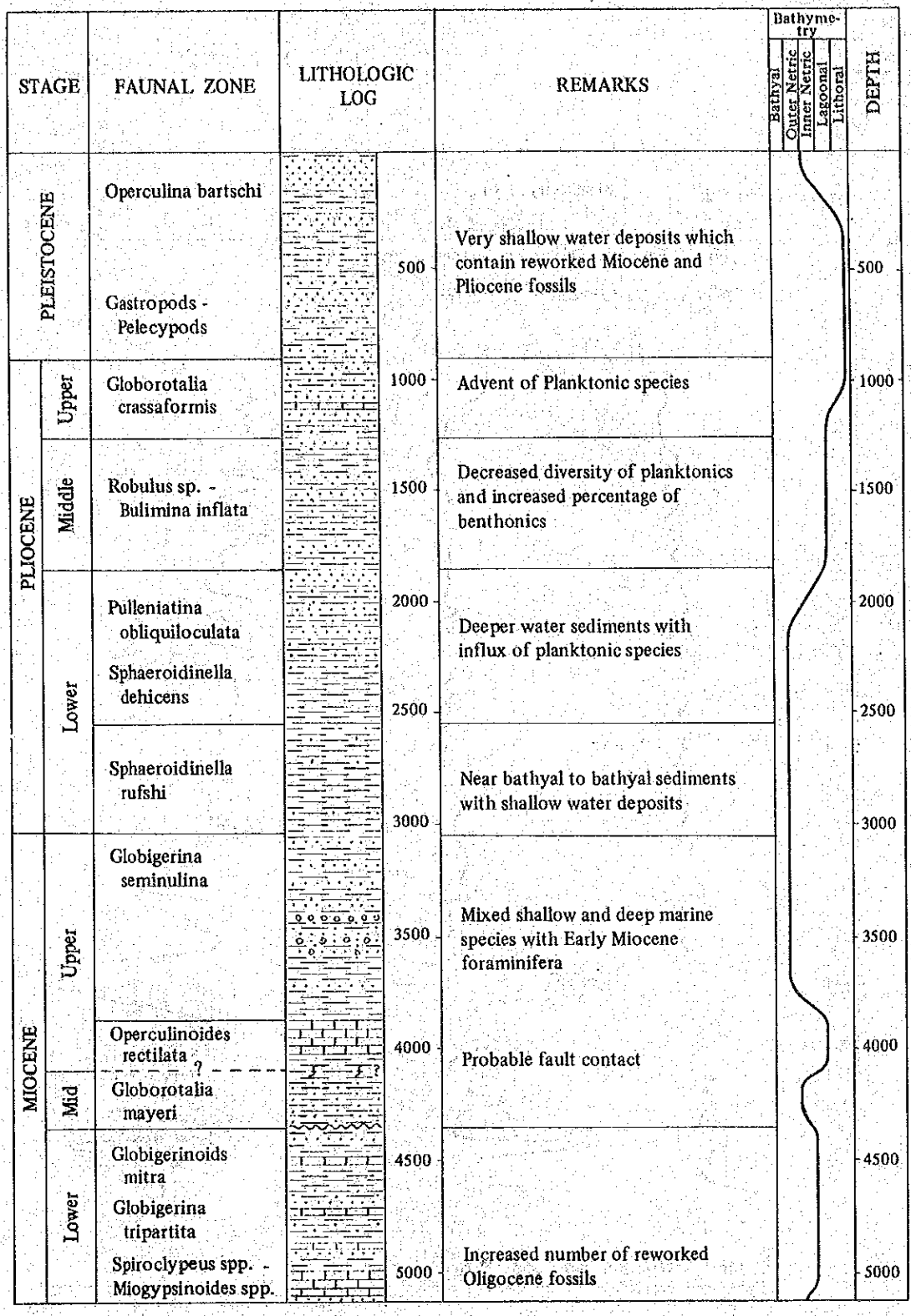
o Basement complex 5,110 - 5,150 ft (1,557.9 - 1,570.1 m)

Composed of olivine basalt.

(Logging)

Sonic logging has been conducted between 735 and 5,129 ft (224 - 1,560 m) (Text-fig. 4-10). The sonic velocity of sandstone, mudstone and alternating sandstone and mudstone in the section shallower than 3,800 ft (1,160 m) ranges from 1.52 to 1.93 km/s, increasing with depth. The fluctuations of sonic velocity between 1,200 and 1,700 ft (366 - 518 m) and between 2,400 and 2,600 ft (732 - 792 m) are assumed to reflect sand layers. The peak of velocity at 3,500 ft (1,070 m) is assumed to correspond to conglomerate. The velocity in the section lower than 3,800 ft (1,160 m) is 1.93 to 3.80 km/s increasing with depth. The peaks at 3,800 - 4,100 ft (1,160 - 1,250 m) and 4,800 ft (1,460 m) correspond to limestones.

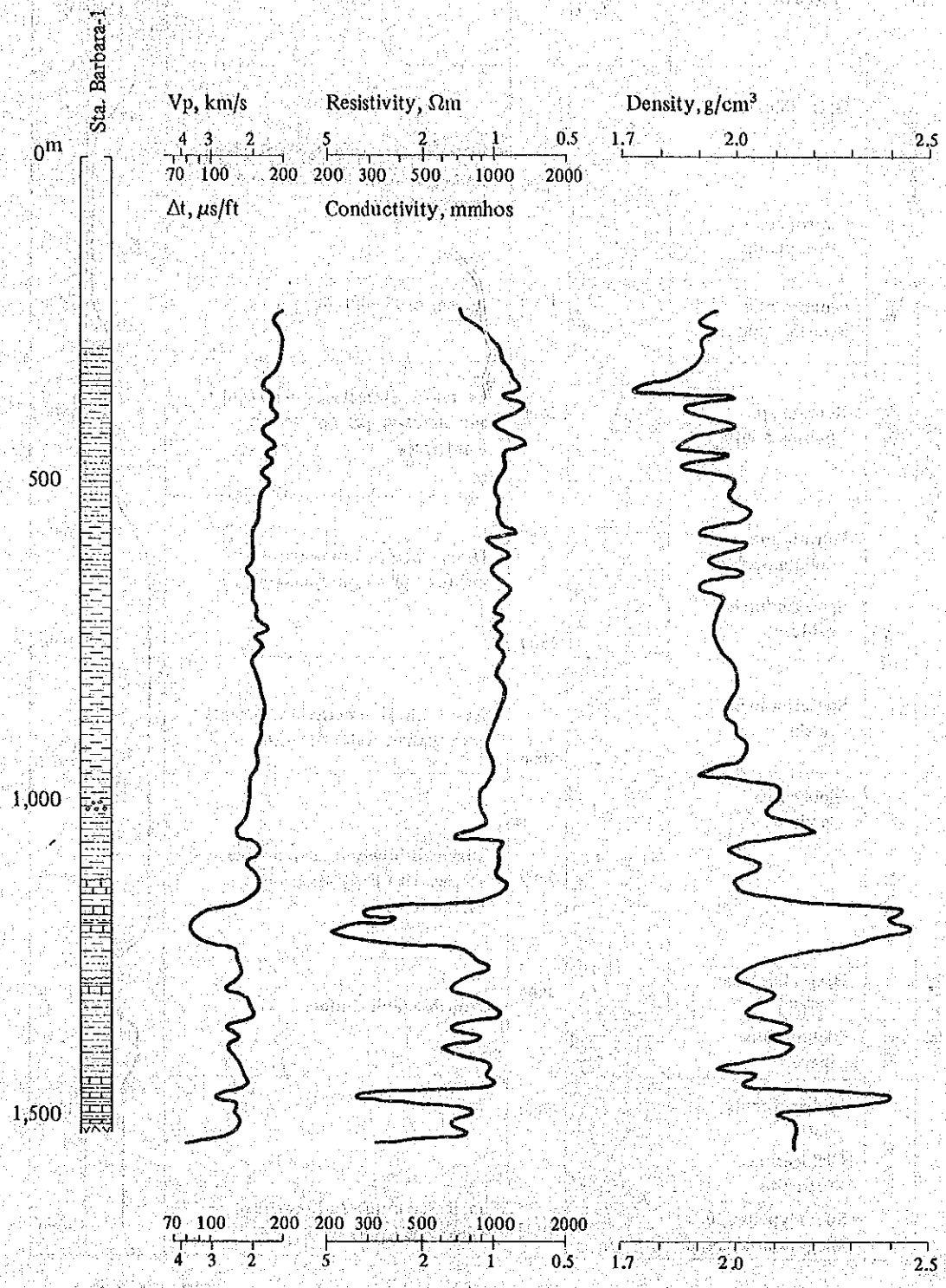
Electric logging has been carried out between 735 and 5,129 ft (224 - 1,560 m) (Text fig. 4-10). The conductivity in the section shallower than 3,800 ft (1,160 m) ranges from 900 to 1,060 mmhos and increases with depth. The fluctuation between 1,100 and 1,500 ft (335 - 457 m) and between 1,950 and 2,300 ft (594 - 701 m) and the peak at 3,500 ft (1,070 m) are assumed to reflect sandstones or conglomerates. The section with a high conductivity shallower than 1,000 ft (305 m) is assumed to indicate invasion of meteoric water. The conductivity in the section deeper than 3,800 ft (1,160 m) ranges from 210 to 1,060 mmhos. The sections with a low conductivity of 210 - 380 mmhos at 3,800 - 4,100 ft (1,160 - 1,250 m) correspond to limestones. The parts with a low conductivity of 600 - 1,060



(PODCO, 1973a)

TEXT-FIGURE 4-9

Lithology, micropaleontology and bathymetry of Sta. Barbara-1.



TEXT-FIGURE 4-10

Sonic velocity, conductivity and density in Sta. Barbara-1.

mmhos among the limestones consist of alternating sandstone and mudstone.

Electric logging has been conducted between 753 and 5,129 ft (230 - 1,560 m) (Text-fig. 4-10). The rock density of this well ranges 1.73 to 2.45 g/cm^3, increasing with depth. The fluctuation observed in the sections shallower than 2,300 ft (701 m) is assumed to be attributed to the development of sandstones. The peaks at 3,800 - 4,200 ft (1,160 - 1,280 m) and at 4,850 ft (1,480 m) correspond to limestones.

Lucena-1 (Text-figs. 4-1, 11, 12, 13)

This well located 2 km west of Lucena was drilled by PODCO during Jan. 3 to Feb. 8, 1973, and abandoned owing to no oil and commercial scale gas. The drilling depth is 6,640 ft (2,024.4 m) and the well bottom reaches basalt. The purpose of drilling this well was to test limestone and sandstone in the Ulian, Dingle and Passi Formations at the top of the anticlinal structure found through the seismic surveys.

The top section of this well to a depth of 1,100 ft (335.4 m) is formed of Pleistocene soft shale intercalated with high porosity sands.

The section between 1,100 and 2,790 ft (335.4 - 841.5 m) is composed of thick mudstone to siltstone, and that between 1,100 and 1,280 ft (335.4 - 390.2 m) has thin sandy intercalations. Between 1,000 and 2,400 ft (304.9 - 731.7 m) many shows of methane were detected.

The section between 2,760 and 4,910 ft (841.5 - 1,497 m) consists of intercalating siltstone-shale, limestone and sandstone. The sandstones are fine to coarse-grained, unconsolidated, low in roundness and poor in quartz. The thickness of the sandstone beds vary from several cm to 20 m, and their porosities are assumed to be 18 to 33% according to logging. This section also has limestone beds and their porosity is 6 - 28%. The limestone with largest thickness and the highest porosity lies at a depth of 3,212 - 3,292 ft (979.3 - 1,003.7 m). According to electric logging the ratio of water saturation of this section is 100%.

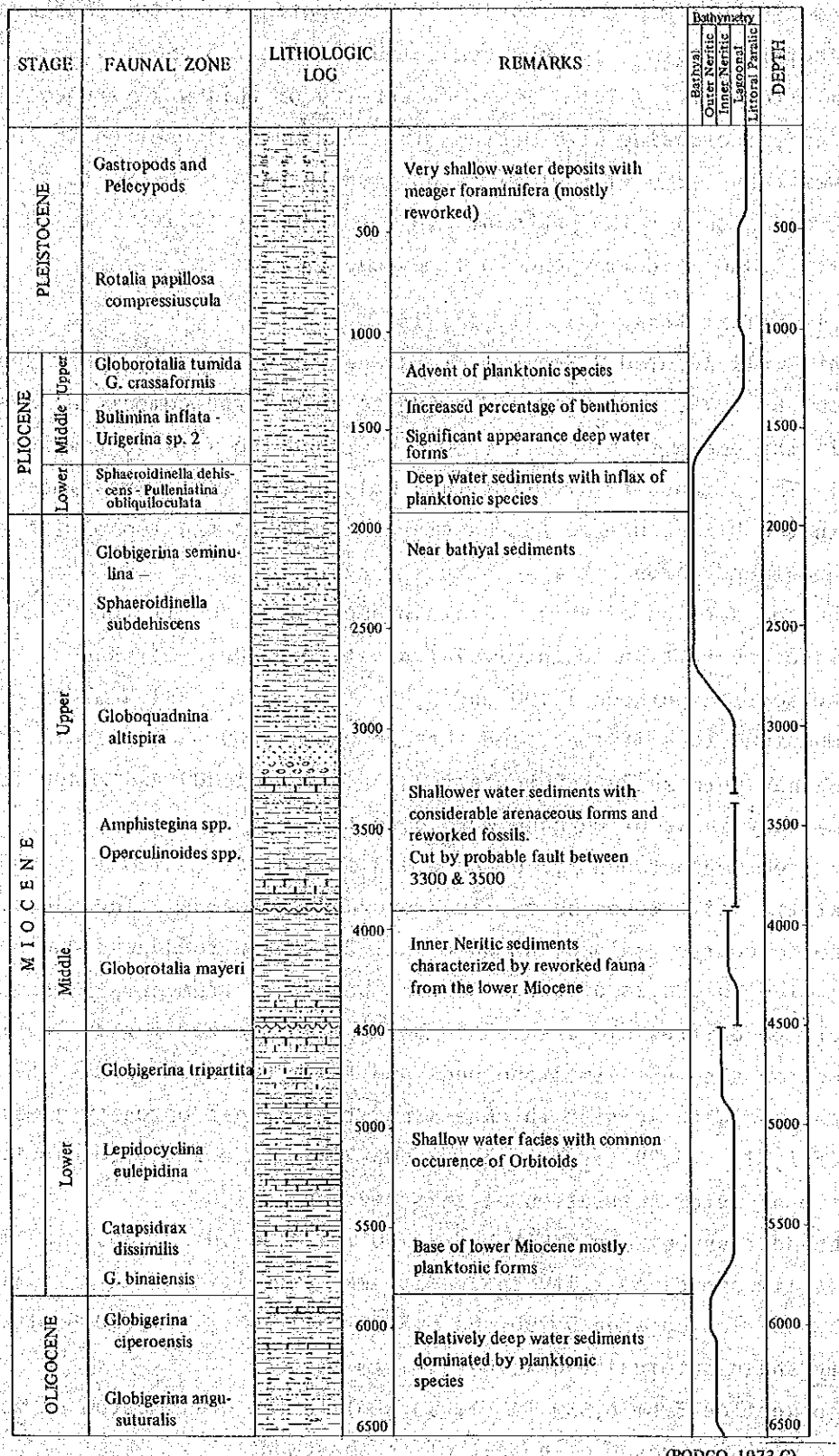
The section between 4,910 and 5,790 ft (1,497.0 - 1,765.2 m) is formed of dense limestone and silty shale with low porosity and permeability.

The section between 5,790 and 6,530 ft (1,765.2 - 1,990.8 m) consists of silty shale intercalated with thin limestones.

The section from 6,530 ft (1,990.8 m) to the well bottom of 6,640 ft (2,024.4 m) is composed of basalt of the basement.

(Logging)

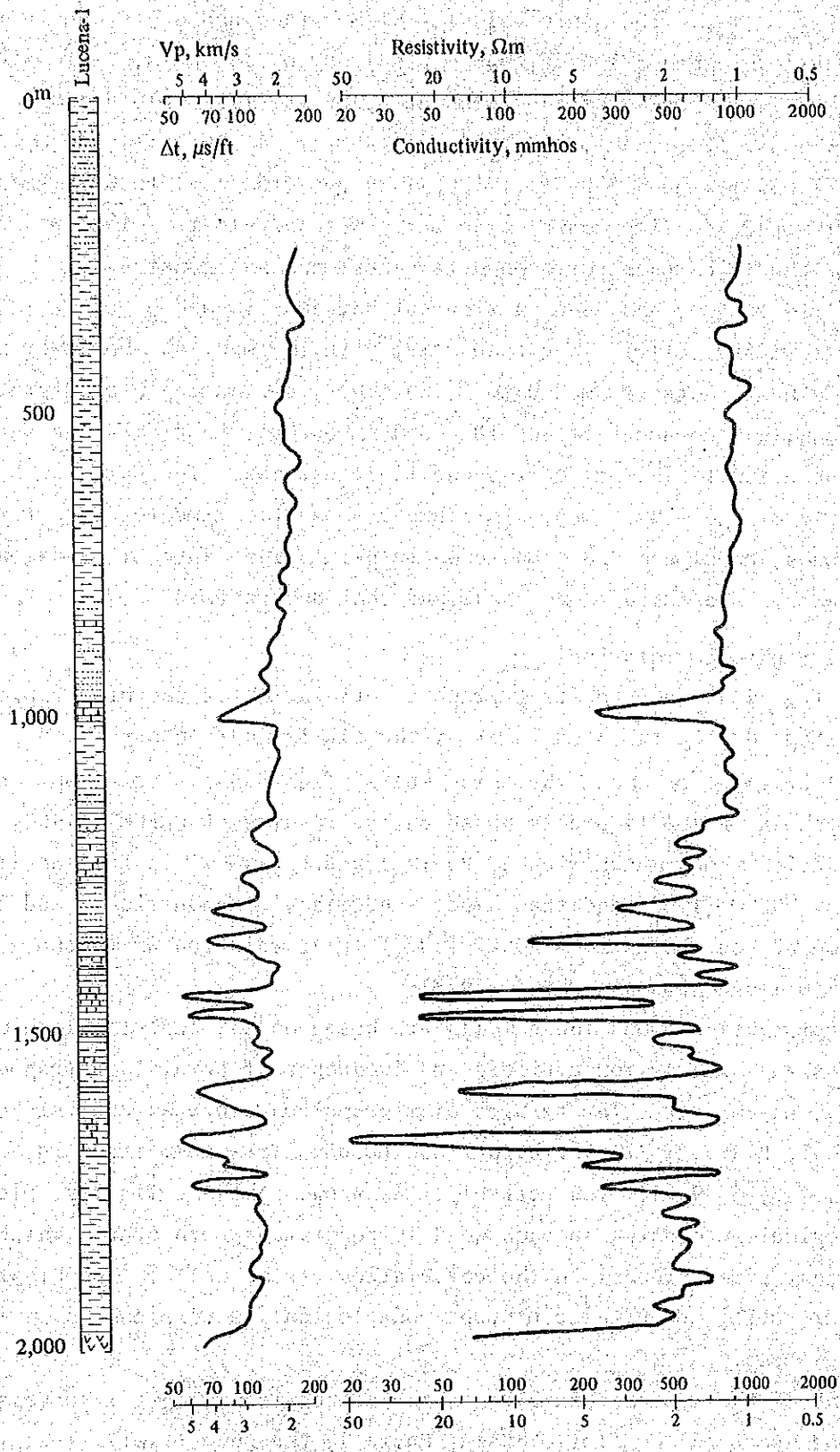
Sonic logging has been conducted between 756 and 6,590 ft (230 - 2,010



(PODCO, 1973 C)

TEXT-FIGURE 4-11

Lithology, micropaleontology and bathymetry of Lucena-1.



TEXT-FIGURE 4-12

Sonic velocity and conductivity in Lucena-1.

m) (Text-fig. 4-12). The sonic velocity of mudstone and sandstone in the section shallower than 3,100 ft (945 m) is 1.60 to 2.46 km/s, increasing with depth. The velocity at the peaks at 3,300 ft (1,010 m), 4,300 ft (1,310 m), 4,450 ft (1,360 m), 4,750 ft (1,450 m), 4,850 ft (1,480 m), 5,500 ft (1,680 m) and 5,750 ft (1,750 m) ranges from 3.81 to 5.54 km/s, which corresponds to limestones. The parts with a velocity of 2.10 - 3.05 km/s among the limestones correspond to sandstones and mudstones.

Electric logging has been carried out between 756 and 6,600 ft (230 - 2,010 m) (Text-fig. 4-12). The conductivity in the section shallower than 3,150 ft (960 m) ranges from 750 to 1,130 mmhos, decreasing with depth. Many peaks with a conductivity of 20 - 300 mmhos distributed in the section deeper than 3,150 ft (960 m) correspond to limestones. The parts with a conductivity of 400 - 940 mmhos distributed among the limestones correspond to sandstones, mudstones and limestones in part. The depth of invasion of meteoric water is assumed to be shallower than 800 ft (244 m).

2) Stratigraphic correlation

Text-fig. 4-13 shows a stratigraphic correlation of the nine exploratory drillings dug in the south part of the Iloilo sedimentary basin. The mutual correlation among the three wells, Tigbauan-1, Oton-1 and San Miguel-1, shown in the figure is based on the results of DALEON (1960). The correlation among Mandurriao-1, Pavia-1 and Leganes-1 is in line with the data by PODCO (1980) and that among Mandrriao-1, Mandurriao-2 and Sta. Barbara depends on the data by PODCO (1977). The relation of Lucena-1 with other wells depends on PODCO (1973).

The correlation among these wells are based on the analytical results of microfossils, mainly foraminifera and frequency of corals, gastropods, pelecypods, algae, etc. The results of micropaleontological analysis of Mandurriao-1, Pavia-1, Sta. Barbara-1 and Lucena-1 are summarized in Text-figs. 4-3, 6, 9, 11, respectively. As shown in these figures, micropaleontological succession in each well is consistent each other, which shows a great effectiveness in the correlation of the wells. The biostratigraphic unit utilized in these micropaleontological successions is "assemblage zone."

As one of the typical examples of the micropaleontological successions in the south part of the Iloilo basin, Pavia-1, the newest well (Text-fig. 4-6), is outlined in quotation from PODCO (1980) as follows:

i) *Rotalia papillosa* var. *compressiuscula*

Gastropods and Pelecypods — Pleistocene

This zone is characterized by yield of *Rotalia papillosa* var. *compressiuscula*, gastropods and pelecypods. It also contains planktonic foraminifera in addition to benthonic *Nonion* and *Elphidium*, but generally the frequency is low. The sedimentary environment shown by megafossils is very shallow turbid water.

ii) *Globorotalia crassaformis* — Late Pliocene

In this zone the ratio of planktonic foraminifera increases sharply, and the ratio with benthonics becomes about equal. Although this zone is represented by *Globorotalia crassaformis*, it also contains benthonic foraminifera frequently including *Rotalia papillosa* var. *compressiuscula*. The bathymetry of the zone is assumed from an increase in the ratio of planktonic foraminifera to be larger than that of the upper zone.

iii) *Bulimina inflata*

Uvigerina sp. 2 — Middle Pliocene

In this zone the ratio of planktonic foraminifera is slightly higher than that in the *G. crassaformis* zone lying above it. However, in the zone of Mandurriao-1 the ratio of benthonics is larger. In the lower part of this zone in Pavia-1, *Pullenia bulloides* which characterizes deep water environment appears and the ratio of benthonics decreases further. This indicates further deeper bathymetry than that of overlying zone.

iv) *Pulleniatina obliquiloculata*

Sphaeroidinella dehiscens — Early Pliocene

A 70 to 80% of foraminifera in this zone is planktonics, and benthonic deep water species *Pullenia bulloides*, *Cassidulina subglobosa*, and *Gyroidina* are yielded from this zone.

v) *Globoquadrina altispira*

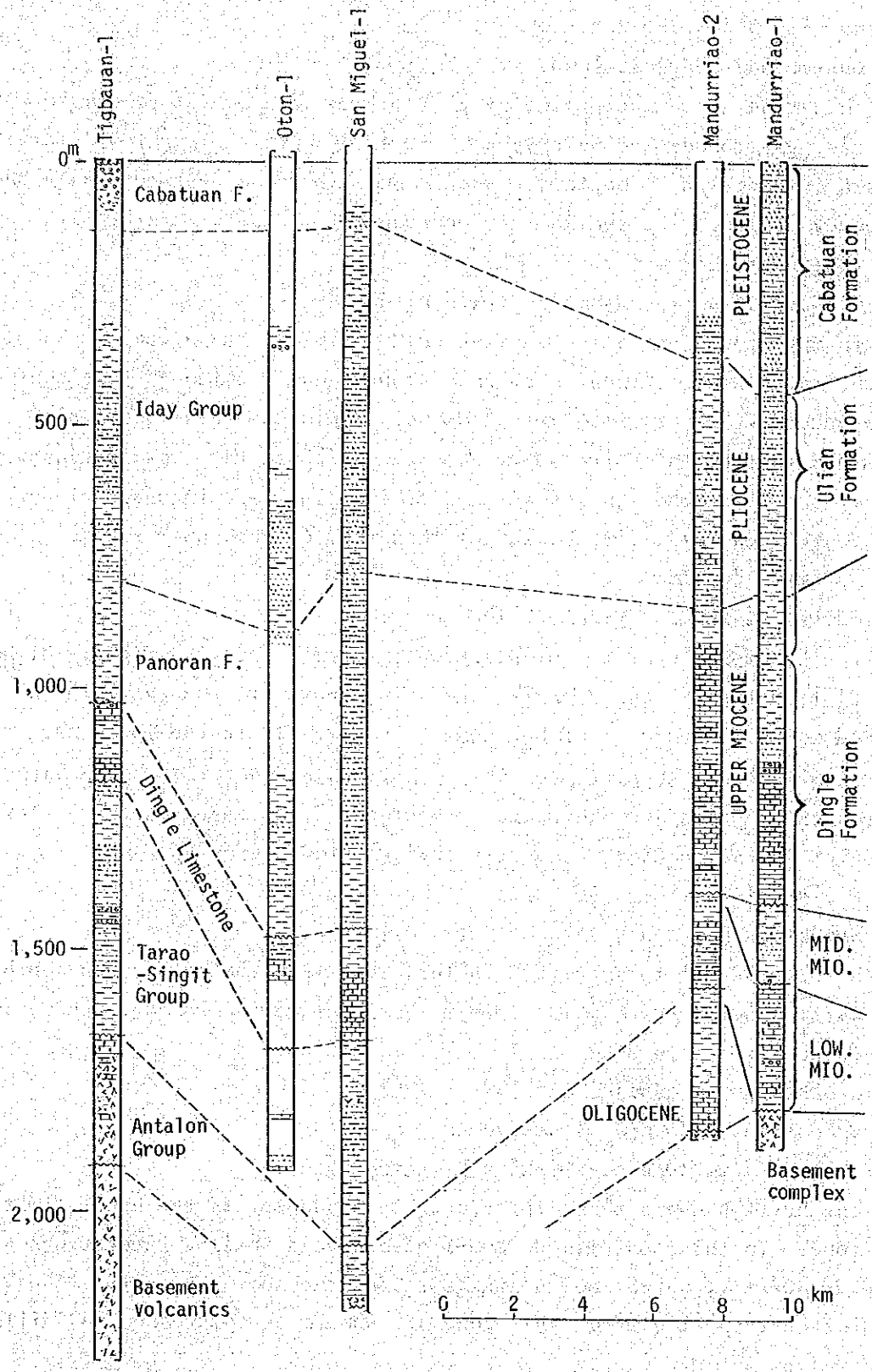
Sphaeroidinellopsis subdehiscens

Sphaeroidinellopsis seminulina — Late Miocene

The horizon where these three species disappear is the upper limit of this zone. In this zone mixed faunas of deep and shallow water types are found frequently, which show an influence of turbidity currents. The foraminiferal specimen from this zone are sometimes compressed and filled with pyrite.

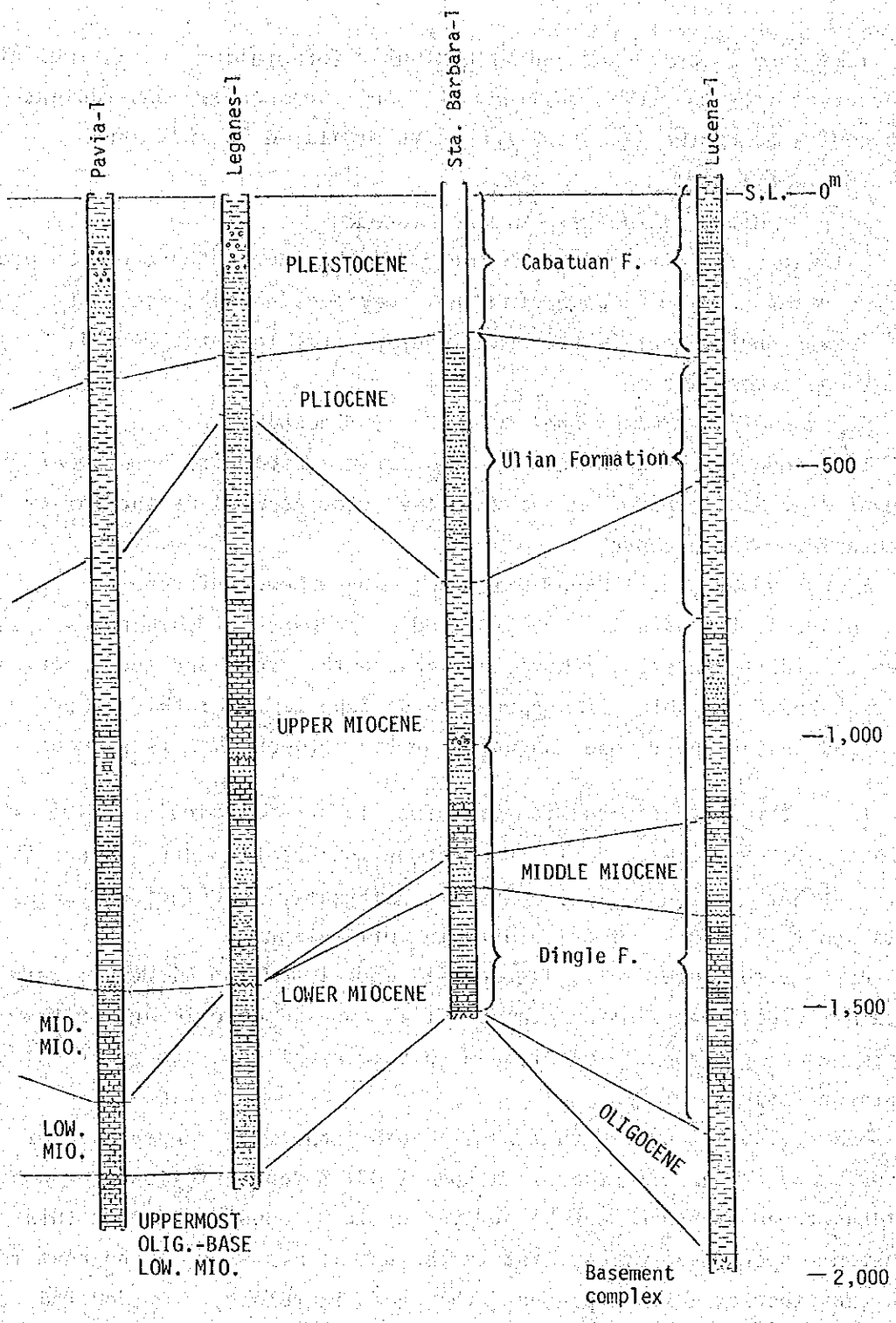
vi) *Amphistegina* sp.

Operculina spp. — Late Miocene



TEXT-FIGURE 4-13

Correlation of geologic successions of nine exploratory drillings in Iloilo basin.


Pavia-1
Leganes-1
Sta. Barbara-1
Lucena-1
S.L.—0m
PLEISTOCENE
Cabatuan F.
PLIOCENE
Ulian Formation
—500
UPPER MIOCENE
—1,000
MIDDLE MIOCENE
Dingle F.
LOWER MIOCENE
—1,500
MID. MIO.
LOW. MIO.
OLIGOCENE
UPPERMOST OLIG.-BASE LOW. MIO.
Basement complex
—2,000

This zone is characterized by benthonic foraminifera which indicates an outer neritic to reefal environment. This sedimentary environment is also confirmed by the limestone facies intercalated in this zone.

vii) *Miogypsina* spp.

Lepidocyclina dehiscens — Middle Miocene

This zone is correlated with the Middle Miocene because of the presence of *Globorotalia mayeri*, *Miogypsina* spp., *Lepidoclina* sp., etc. The sedimentary environment is probably inner neritic to inter-reefal.

viii) *Miogypsinoides* spp.

Lepidocyclina (Eulepidina) sp. — Early Miocene

This zone is characterized by *Globigerina tripartita*, *Praeorbulina trangitoria*, *Globigerinoides subquadratus*, etc. as well as the larger foraminifera listed above.

ix) *Spiroclypeus* spp. — Upper Oligocene — Base Lower Miocene

This zone in Pavia-1 is constituted by back-reefal carbonates. Since there is a difference in lithofacies between this zone and the upper zone and reworked fauna which is supposed to be supplied from this zone is contained in the upper zone, an unconformity between them is assumed.

The bathymetry assumed from microfossils and lithologic facies is shown in Text-figs. 4-3, 9, 11 in addition to Text-Fig. 4-6. These figures indicate that a chronological change in bathymetry is coincident among each wells and this offers effective data in correlation.

Because the three wells, Tigbauan-1, Oton-1 and San Miguel-1, were drilled in rather older years, stratigraphic division and geologic age of them were determined slightly differently, and so some problems in correlation still remain unresolved.

BANDY (1960) reported that in Tigbauan-1 the first appearance of *Globorotalia truncatulinoides* is around 1,024 m depth, followed by continuous yielding to about 656 m depth. At present it is considered that this planktonic species appeares first in the Lowest Pleistocene and that is an important species which represents the age. Therefore, provided that this identification is correct and no contamination exists, the Pliocene/Pleistocene boundary in Tigbauan-1 lies below 1,024 m and the Pliocene of this well is very thin or is lacking. The lack of the Pliocene affects not only interpretation of stratigraphy and geologic structure, but also surveys of kyosui-sei-gasu deposits, so that thorough study is required in the future.

5. Geological structure

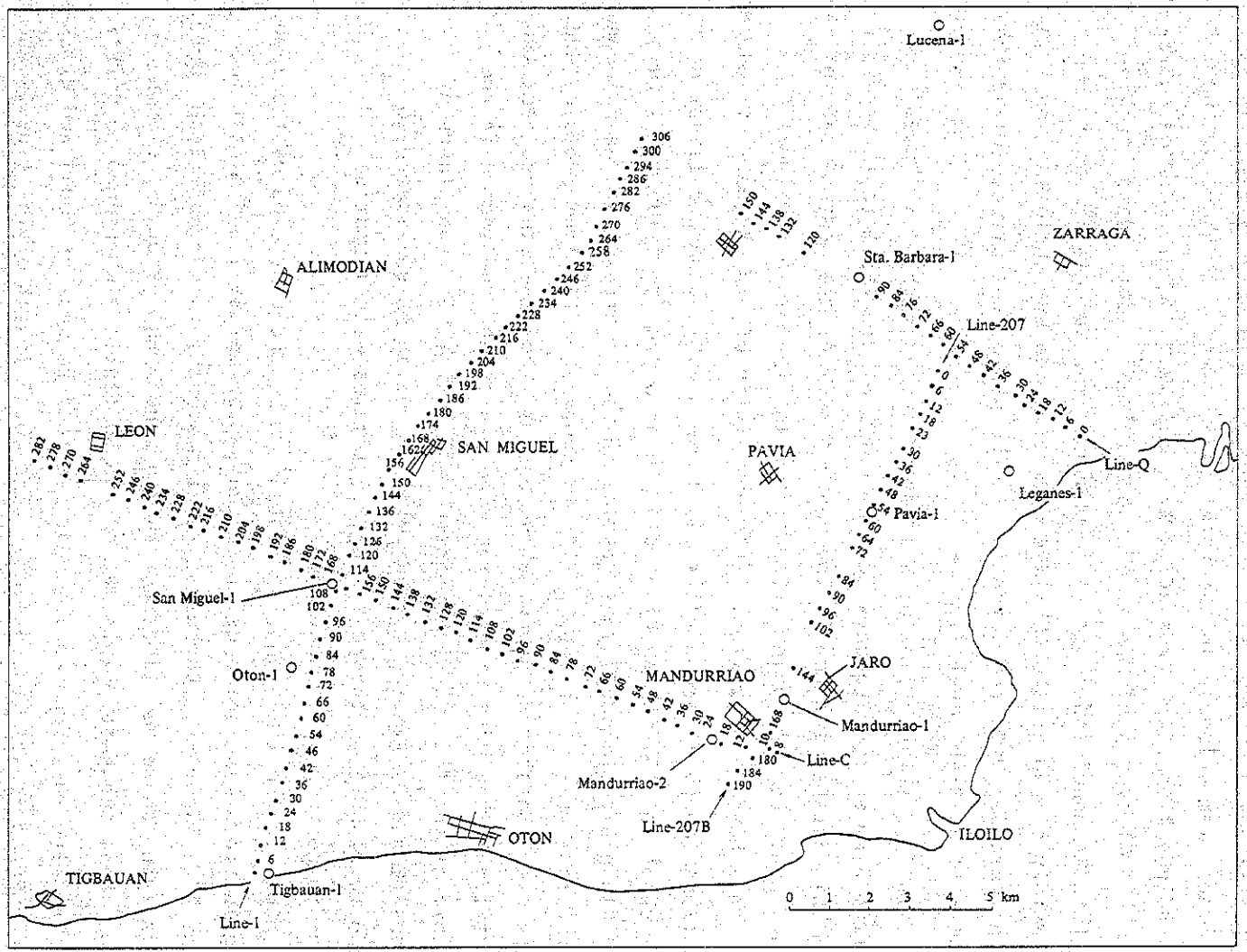
1) Seismic profile

In the plain area of the Iloilo basin PODCO has conducted seismic surveys by reflection method for oil and natural gas exploration. The number of the seismic lines and the total length amount to about 50 and several hundreds kilometers, respectively. The surveys were carried out by contract with GSI, INDEX of U.S.A. by the 6-fold horizontal data stacking method with 24 channel and 12 group geophones. The seismic lines are constituted mainly of two sets of SSW-NNE direction and ESE-WNW direction. The former runs parallel with the direction of the geological structure and the latter meets it at right angles.

Line-Q This is a seismic line with a total length of about 10 km running ESE-WNW from 3 km east of Leganes to 1 km north of Sta. Barbara (Text-figs. 5-1, 2). This line is located in the eastern half of the central part of the basin. Near the shot point 100 on this line the exploratory drilling Sta. Barbara-1 have been drilled. In the vicinity of Sta. Barbara two planes of reflections (A and B) are identified; Plane A corresponds to limestone with a thickness of 100 ft (30 m) at a depth of 3,900 ft (1,190 m) of this well, and Plane B corresponds to sandstone in the lower part of the Pliocene. Plane B inclines west at an angle of 8° in average on the line profile, and disappears near the shot point 66 in the east side of the line and near the shot point 126 in the west side of the line. Although the record in the eastern part of the line is discontinuous and indistinct, two planes of reflections (C and D) are identified; Plane C, which is considered to correspond to Plane A in the west side, correlates with limestone. Plane D is assumed to correspond to sandy beds.

The depth to the limestone is about 800 m in the east side of the line, deepening in tiers west northwest to reach approximately 1,500 m near the shot point 138. Near Sta. Barbara-1 the limestone forms an anticline, but the strata lying above the limestone show a monoclinal structure dipping west-ward. Near the shot points 18, 42 and 66 faults are assumed to exist.

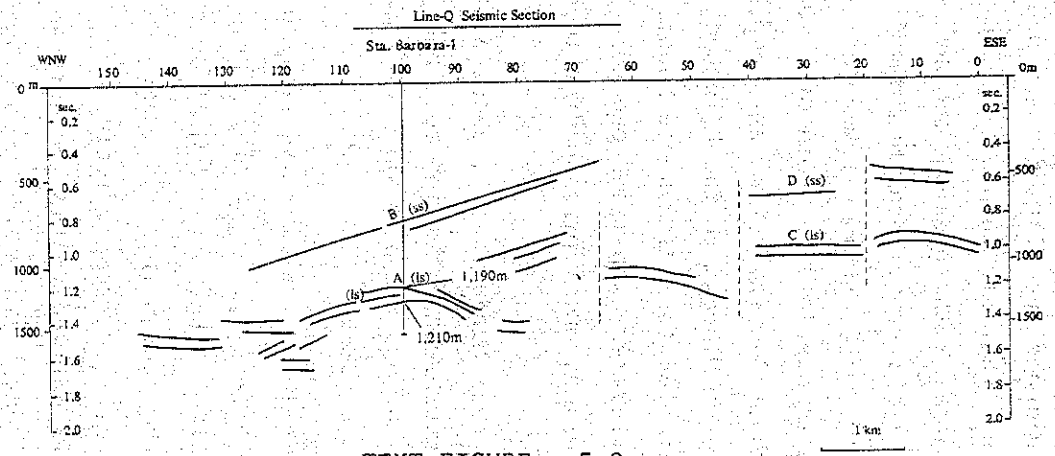
Line-C The line runs from near Mandurriao to 4 km west of Leon, and crosses the basin ESE-WNW (Text-figs. 5-1, 3). The total length of the line is about 23 km. Near the shot point 16 and the shot point 168 along the line the exploratory drillings Mandurriao-2 and San Miguel-1 have been drilled, respectively. In the vicinity of Mandurriao-2 three planes of reflections



(PODCO, 1979)

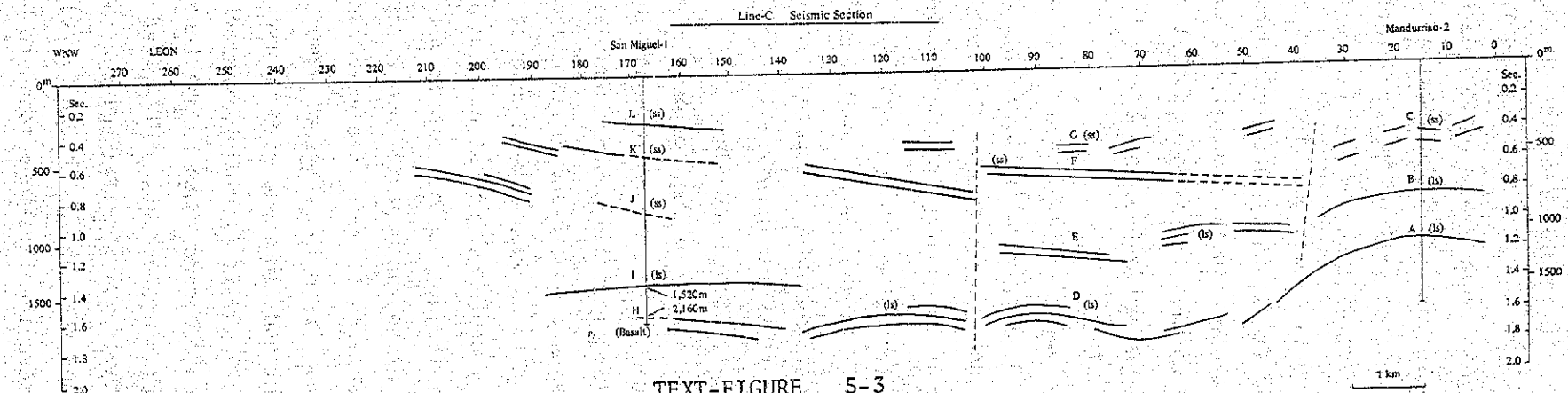
TEXT-FIGURE 5-1

Shotpoint location map of seismic survey.



TEXT-FIGURE 5-2

Analysis of seismic profile of Line-Q.



TEXT-FIGURE 5-3

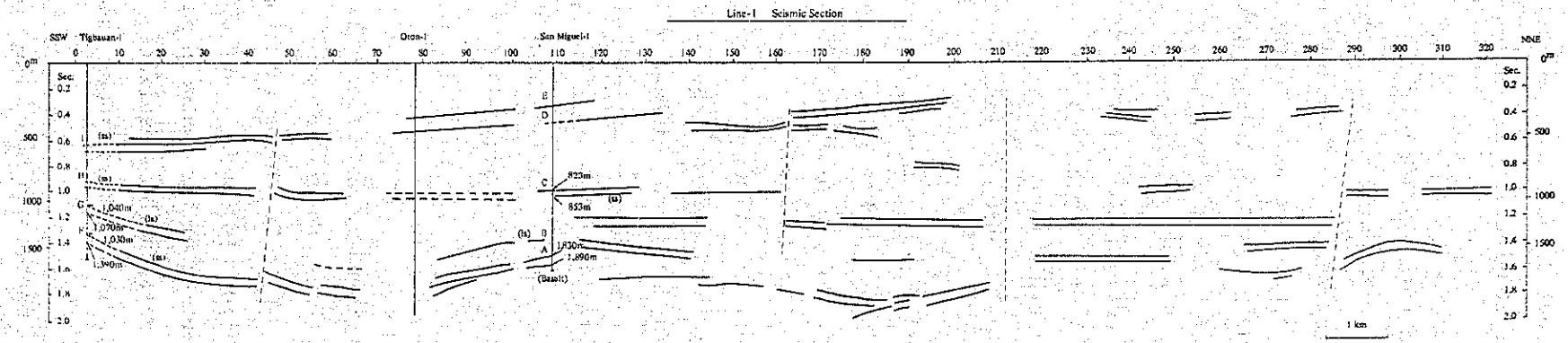
Analysis of seismic profile of Line-C.

(A to C) are recorded; it is considered that Plane A and Plane B correspond to limestones at a depth of 3,000 ft (914 m) and that at a depth of 3,800 ft (1,160 m), respectively, and Plane C is correlated with sandstone in the alternating sandstone and mudstone of the Upper Pliocene. Near San Miguel-1 five planes of reflections are distinguished (H to L); it is assumed that Plane H, Plane I and Planes J to L correspond to basalt at a depth of 7,100 ft (2,160 m), limestone with a thickness of about 400 ft (122 m) at a depth of 5,000 ft (1,520 m) and sandstones of the Upper Miocene to the Pliocene, respectively. In the vicinity of the shot point 84 four planes are identified (D to G). It is assumed that Plane D correlates with limestone corresponding to Plane A, and Planes E to G with sandstones corresponding to Planes J to L.

The depth of the limestone is shallowest near Mandurriao-2, about 3,800 ft (1,160 m), gradually increasing in a west northwest direction to reach about 2,000 m or more near the shot points 72 and 138. The fault is assumed to be near the shot points 36 and 102.

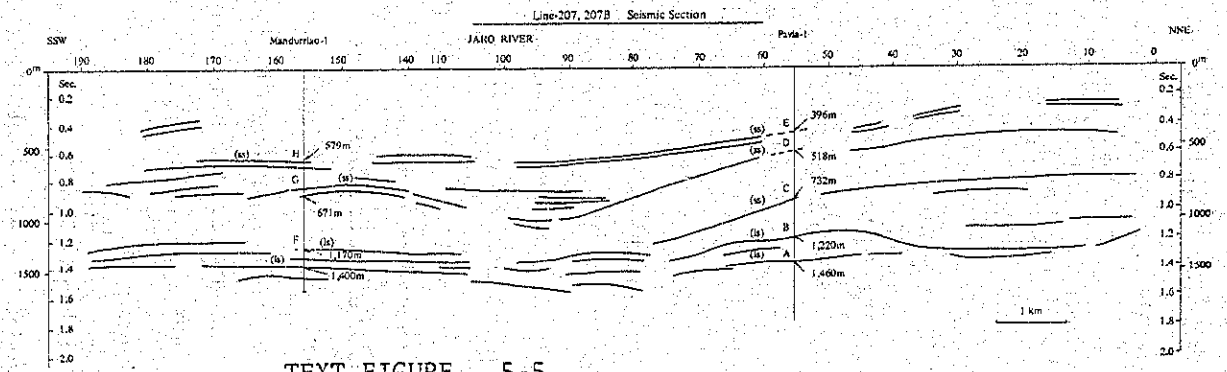
Line-1 This line with a total length of about 40 km runs SSW-NNE from near Tigbauan-1 to about 8 km northwest of Pototan (Text-fig. 5-1). The planes of reflections between the shot points 1 and 318 in the southern half of the line are illustrated in Text-fig. 5-4. Near the shot points 3, 78 and 109 Tigbauan-1, Oton-1 and San Miguel-1 have been drilled, respectively.

Five planes of reflections (A to E) are identified in the vicinity of San Miguel-1; Plane A corresponds to basaltic rocks with a thickness of about 200 ft (61 m) at a depth of about 6,000 ft (1,830 m) of San Miguel-1. It is assumed that Plane B and Plane C correspond to limestones intercalated with sandstones with a thickness of about 400 ft (122 m) at about 5,000 ft (1,520 m) depth and sandstone with a about 100 ft thickness (30 m) at about 2,700 ft (823 m) depth, respectively. Plane D and Plane E are related to sandstones in the Upper Pliocene, assumedly. Near Tigbauan-1, four planes of reflections (F to I) are discerned. Plane F and Plane G correspond to sandstone with a thickness of about 250 ft (76 m) at a depth of 4,300 ft (1,310 m) and limestone with a thickness of about 100 ft (30 m) at a depth of about 3,400 ft (1,040 m), respectively. Probably, Planes H and I correspond to sandstones in the Lower Pliocene. The plane of reflection from the limestone undulates gently, and forms anticlinal structures near Tigbaunan-1, San Miguel-1 and the shot point 185. In the vicinity of Oton-1 and the shot point 300, synclinal structures are recognized. Plane C lying above the limestone tends to become horizontal, in general, and the



TEXT-FIGURE 5-4

Analysis of seismic profile of Line-1.



TEXT-FIGURE 5-5

Analysis of seismic profile of Line-207, 207B.