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AUSTRALIAN AQUITAINE PETROLEUM PTY. LTD.

NORTHERN TERRITORY

OP 186

004051

BNT-81 SEISMIC SURVEY

INTERPRETATION REPORT

GP/135/82

G. MAGNIEN

October 1982

ONSHORE

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PR82178C 3of3

CONTENTS

LIST OF PLATES

* *

LIST OF FIGURES

		Dwg. No.
FIGURE 1	Permit Location Map (1:1000,000).	19187 ✓
FIGURE 2	Line Location Map.	21058 ✓
FIGURE 3	Stratigraphic Table.	19917 ✓
FIGURE 4	Major Structural Elements.	17931 ✓
FIGURE 5	Geological and Structural Sketch Map.	21176 ✓
FIGURES 6a-n	Uphole Velocity Surveys- Time Depth Plots.	20559-20563 20566-20574

LIST OF APPENDICIES

✓ APPENDIX A	Field Operations Report - Horizon Exploration.
APPENDIX B	Experimental Programme. (not get completed 2/11/82)
✓ APPENDIX C	Processing Report - Digicon.

INTRODUCTION

The BNT-81 Seismic Survey was conducted by Horizon Exploration (International) Limited in Permit OP 186, Northern Territory, for Australian Aquitaine Petroleum Pty. Ltd., Alliance Petroleum International Pty. Ltd, and Vamgas Ltd. The acquisition phase began on July 14, 1981, with line clearing and surveying. Seismic recording commenced on August 16, with an experimental programme and was completed on October 1, 1981. A total of 123.6 km of Vibroseis recording was obtained, all with 24-fold coverage.

Seismic data processing was performed by Digicon International at their Digital Processing Centre in Singapore between October 1981 and March 1982. Twentyfour-fold, stacked seismic sections were output, employing correlation, deconvolution, time-variant filtering and migration for some of the lines.

The BNT-81 seismic data was interpreted by Australian Aquitaine Petroleum Pty. Ltd.'s geophysical staff in Sydney. Despite all the attempts made during the field acquisition and processing stages to get the best possible data with the Vibroseis method, the results generally remained poor in most areas. A slight improvement was noticed, however, in the zones where the seismic markers showed some continuity on the previous data.

1. GENERAL INFORMATION

1.1 Purpose of the Survey

The interpretation of the BNT-80 Seismic Survey, combined with information from the Oakes Creek and Border Creek surveys, shot for Australian Aquitaine Petroleum Pty. Limited in 1967 and 1972, confirmed the existence of a high axis dipping northeasterly from the Pincombe Range Precambrian Basement outcrops into the basin. The Keep River No. 1 well was drilled in 1969 on the continuation of that axis and terminated at 4761m in quartz sandstones attributed to the Cockatoo Formation (Late Devonian). The overlying formation consisted of Devonian limestones (Ningbing Formation) backreef facies. Gas shows were encountered in sands interbedded with marine shales from the Milligans Beds (Early Carboniferous).

The BNT-81 Survey was designed to tentatively investigate the presence of either reefal buildups or detritic accumulations along the Pincombe High axis, updip from Keep River No. 1 (Pincombe North and South areas; Fig. 2). Another four lines were shot to get a better definition of a seismic anomaly situated on the eastern flank of the Burt Range Syncline which runs parallel to the Pincombe High (Weaber grid; Fig. 2). The anomaly was noted during a reinterpretation of the Burt Range Survey shot in 1970 (Interpretation Report (Reference 1)).

1.2 Location and Participants

The BNT-81 Seismic Survey was conducted in the northwestern corner of the Northern Territory, in Permit OP 186, as shown in Figs. 1 2. The survey area is located within the onshore part of the Bonaparte Basin which straddles the Western Australia-Northern Territory border and extends seawards under the Timor Sea. Australian Aquitaine Petroleum was Operator for this survey, with Alliance Petroleum International Limited and Vamgas Limited being the other participants.

1.3 Field Operations

1.3.1 General

A total of 123.6 km of new data was recorded by Horizon Exploration International Ltd.'s Party LC4 V, using Vibroseis as the primary energy source. A description of the field operation is presented in the Field Operations Report by Horizon Exploration and is included in this report as Appendix A. The average surface coverage per actual production-day was 3.9 km (or 78 vibrated points). Supervision on behalf of the participants was carried out by Messrs. G.Magnien, S.Mackie and P.Poulain from Aquitaine's geophysical division.

1.3.2 Access and Line Clearing

Access to the zone was provided through the gravel road from Kununurra to Legune Station. Most of the lines on the Pincombe Grid had to be cut through dense bush and the use of rather heavy equipment (DG and D8 size bulldozers) proved to be adequate. The lines from the Weaber grid were cut through uneven black soil plains with uneven ground and heavy grading work was required. A crossing was prepared across the Keep River, and a long detour was necessary to record data along line BNT81-313 which extends on both sides of the riv

1.3.3 Topographic Map

The area is covered by the Legune sheet of the 1:100,000 series produced by the Department of National Mapping. Its accuracy was quite adequate for the present work. A computer plot at scales of 1:100,000 and 1:50,000 of all lines was produced by Wescom in their offices in Perth, from a magnetic tape prepared with the co-ordinates computed by Horizon's surveyors. These plots were integrated into the pre-existing base maps (see Section 3.1).

1.3.4 Surveying

The survey was tied to three pre-existing benchmarks previously set and used by Aquitaine. One of them, called M60N, is situated on the Western Australia - Northern Territory border between lines BNT81-301 and 303. Another one, AAP BM1, is located on the western bank of the Keep River near the eastern end of line 307.

Shortly after the survey was completed, the co-ordinates for M60N and AAP BM1 were checked by Decca Survey Australia using their JMR-1 Satellite Doppler System. The calculation of shotpoints co-ordinates by Horizon were based on the uncorrected benchmark co-ordinates which were the only ones available at that time. However, the small magnitude of discrepancies observed between these and the new set did not justify recomputation of all shotpoints, as shown hereunder:

	M60N	AAP BM1
Previous X (1)	499,910	511,636
Corrected X (2)	499,900	511,618
Delta X in metres	10	18
Previous Y (1)	8304,774	8313,714
Corrected Y (2)	8304,762	8313,673
Delta Y in metres	12	41

(1) = used by Horizon.
(2) = established by Decca.

The Weaber grid (lines BNT81-308, 309, 311 and 313)was tied to AAP BM3, a new benchmark set by Decca for which provisional co-ordinates were available. There again, the difference with the final co-ordinates was considered as neglibible.

	AAP BM3
Provisional X	515,691
Final X	515,691
Delta X	0
Provisional Y	8298,062
Final Y	8298,055
Delta Y	7

(all co-ordinates are in metres).

The line bearings were established using a Wild T1A theodolite, with sun shots observations conducted before starting each line, and at least once a day. Distance along the lines were measured using Topofil and checked every three days against a calibrated chain. In addition, all distances were further checked with an EDM. As most of the lines did not tie into a loop, double run was common practice.

The geophysical co-ordinates computed by Horizon's surveyors refer to the Australian National Ellipsoid (1966). They were reduced to the Universal Transverse Mercator Projection, Zone 52, Central Meridian 129^{o} E Longitude. The system used for elevations was the Australian Height Datum.

An horizontal and vertical loop misclosure map is enclosed (Pl. 1).

The problems encountered in establishing the basemap are detailed in Section 3.1.

1.3.5 Recording

Recording was accomplished with a GeoSource MDS 10 Instantaneous Floating Point (IFP) 48 channels recording system, in connection with GeoSource SMMI Summer and a GeoSource DC 2400 Correlator. Record length was 19 seconds (16 seconds on line BNT81-302 including 4 secs. listening). Sampling rate was 4 ms.

As the results of the BNT-80 survey was generally disappointing, the following parameters were changed in an attempt to improve the quality at the data acquisition stage.

- The fold coverage was increased from 12-fold to 24-fold for the whole grid;
- the geophones spread was centred on each station while the vibrating pattern was centred between stations which increased the filtering effect of the stacking process;
- the group interval was decreased from 80m to 50m along the lines;
- a more extensive experimental programme was performed prior to the data acquisition phase.

A summary of the parameters actually used during the survey is given in the Operations Report (Appendix A). The experimental programme was conducted over two areas selected along line BNT81-302 as being situated respectively in a good results and bad results zone. A whole range of tests were performed in the former zone and noise and production tests in the latter zone. Test details and conclusions are presented in Appendix B. The geophones spread parameters were kept identical for the whole survey, and the vibrating pattern was slightly varied as the results of the experimental programme became available.

The experimental programme started on August 16 and was designed to last for one-and-a-half to two days. However, repeated equipment failures considerably delayed its completion, and production recording only began on September 1.

1.3.6 Low Velocity Layer (LVL) Studies

As the poor quality of most of the BNT-80 data suggested a static correction problem, more emphasis was put on the weathering control during the BNT-81 survey. This was achieved through a relatively close interval between the refraction spreads along the lines (900m, spread length 300m) and uphole velocity surveys made at the different locations.

The interpretation of the refraction data did not create any particular problem. The computed corrections were generally in good agreement with the measured uphole times, although the interpretation occasionally differed. The holes were initially planned for a total depth of 100m, however, this was reduced to 60m due to difficult drilling conditions through hard sandstones. The charges were placed separately for each shot. The time-depth plots are presented in Figs. 3a to m, and a comparison between the computed and observed corrections is given below:

Line	S.P.	Observed Corrections(ms)	Computed Corrections(ms)
BNT81-302	174	- 17	- 17
BNT81-302	247	- 14	- 18
BNT81-302	294	- 14	- 12
BNT81-302	302	- 19 ?	- 19
BNT81-302	313	- 24	- 22
BNT81-302	328 (int.305)	- 19	- 20
BNT81-302	355 (int.307)	- 17	- 18
BNT81-302	384	- 21	- 21
BNT81-300/305	167	- 27 ?	- 26
BNT81-305	234	- 16	- 15
BNT81-305	256	- 22	- 25
BNT81-305	305	- 24	- 14
BNT81-307/306	342	- 19	- 22
BNT81-311	270	- 19	- 19

Note: A uniform replacement velocity of 3000m/s was used to reduce the corrections to the seismic datum (M.S.L) when interpreting the refraction data.

1.4 Data Processing

Digital processing of the BNT-81 survey field tapes was performed by Digicon at their Singapore Processing Centre.

A test programme was conducted before production processing commenced. A processing report prepared by Digicon is included as Appendix C, which describes in detail the procedure used to process the data.

As for the BNT-80 survey, the generally poor quality of the seismic records hampered the processing, and resulted in long delays as repeated attempts were often necessary to tentatively improve the sections.

- Field Static Corrections (see Section 1.3.6)

  An attempt was made to use Digicon's programmes based on the exploitation of first breaks to generate static corrections. Although the first arrivals generally proved to be suitable for picking, the programmes could not work efficiently due to the high velocities recorded in the superficial layers, and the project was abandoned.

- Velocity Filtering

  No velocity filtering was applied to the records, as it was determined that the stacking procedure achieved the same type of filtering effect (e.g. for the airwave).

- Deconvolution

  Tests were conducted on line BNT81-302, and a 16 ms gap deconvolution was selected with a 120 ms operator length and 1% white noise. Alternatively, a spiking-type deconvolution also proved to be suitable on the tested section.

- Velocity Analyses

  The Bonaparte No. 1 and 2, and Keep River No. 1 wells velocity functions were used as a reference for picking the velocity analysis. A typical section would show a high average velocity in the shallow formations (down to 0.5 s), which remains more or less constant or may even decrease through the black shales, then increase below the surface of the carbonates where present.

  Digicon's SVELFAN type of velocity analysis was used for producing the initial stack. These analyses display, side-by-side, a series of common depth point gathers for several velocity functions and a velocity vs time-coherency plot.

However, picking the correct velocity was difficult when the signal to noise ratio was poor, and Digicon suggested that only continuous velocity stacks should be run. This was used for producing final stacks.

- Residual Static Corrections

This step was quite efficient in the areas where the data quality was reasonable. It did not bring any improvement elsewhere.

- Time Variant Filtering

One filter was applied to all the lines; its design was as follows:

0	s	12-60 Hz
1.5	s	12-45 Hz
2	s	12-43 Hz
3	s	13.5-40 Hz
4	s	15-30 Hz

- Migration

In order to assist the interpretation, three lines (BNT81-303, 307, 311) were migrated, using Digicon's Wave Equation Migration process (finite difference method). The layer thickness was 40m.

- Reprocessing

Lines BNT80-204 and 207 were reprocessed using the same sequence and parameters in order to make a consistent set of data with the BNT-81 lines.

- Documents Produced

The final sections produced are the final 24-fold stacked lines which underwent all the processing stages. The weathering depth and amount of residual static correction applied were displayed on top of each section.

The tapes kept after processing are the uncorrelated field tapes, the CDP gather tapes and the final stack tapes (unfiltered and unmigrated).

The quality of the results will be discussed in the interpretation section.

2. GEOLOGY AND PREVIOUS EXPLORATION

The geological part of this section is taken largely from R. Laws' "The Petroleum Geology of the Onshore Bonaparte Basin" (1).

2.1 Geology and Basin Development

The opening of the Bonaparte Gulf Basin in the Early-Mid Palaeozoic is largely regarded as resulting from divergent left-lateral wrenching within the NE trending Halls Creek Mobile Zone.

Veevers (1976) considered that the initiation of both the Bonaparte and Canning Basins were related to the failed arms of the crustal fracture system which gave rise to the Thethys Ocean.

The extrusion of widespread lavas of the Antrim Plateau Volcanics in the Late Palaeozoic and Early Cambrian is considered to mark the initial stages of plate divergence.

The eastern margin of the basin is formed by the SW-NE Cockatoo Fault which is part of the Halls Creek Mobile Zone System, while the western margin is expected to be more of a rift margin type, with downward faulting towards the basin. However, gravity and photogeological interpretation show it is also affected by faulting parallel to the Halls Creek fracture system.

The stratigraphic geology of the area is known mainly from outcrops and from three wells, two of them drilled in permit EP 126 (Bonaparte No. 1 and 2) and the third one in OP 186, Northern Territory (Keep River No. 1).

A Stratigraphic Table is presented as Figure 3.

2.1.1 Pre-Devonian

The Precambrian basement outcrops largely southwest of the permit, and also forms a prominent high feature known as the Pincombe Inlier (see Fig. 1) which trends northeasterly and separates the basin into the Carlton Sub-basin to the west of the ridge, and the Burt Range

Syncline to the east. This structural barrier seems to have been in existence from the start of deposition, as different facies can be found on either side for formations of the same age. To summarise, open sea conditions existed west of the Pincombe Ridge, while shallower and more lagoonal facies were deposited to the east in the Burt Range Syncline.

The Precambrian basement consists mainly of low grade to non-metamorphic formations including sandstones, conglomerates, etc.; these formations are well bedded and can undoubtedly produce seismic reflections.

Deposition in the basin started with Cambro-Ordovician clastics and carbonates, unconformably overlying the Antrim Plateau Volcanics. Their distribution in the subsurface is unknown. Salt has been encountered in wells located on diapiric structures offshore. The salt is of pre-Late Devonian age, and by analogy with the Canning Basin, was probably deposited throughout much of the Silurian and Early Devonian.

2.1.2 Late Devonian to Permian

The sequence of main interest as far as petroleum is concerned is of Late Devonian to Early Carboniferous age. It is characterised by coarse clastics along the basin margin, grading basinwards through carbonates to shales and silts. With a maximum drilled thickness of 4200m in Keep River No. 1, the basic stratigraphic framework was established by Veevers and Roberts (1968).

- Cockatoo Formation

  The Cockatoo Formation exceeds 1500m in thickness and outcrops widely around the flanks of the basin and within the Ragged Range and associated outliers to the south. Conglomerates are well developed along the faulted eastern basin margin and grade rapidly basinwards to marine sandstones.

Coarse sands are also present along the western fringe of the basin, with interbeds of dolomite, marl and limestone increasing to the east and north. The fossil content is varied and occasionally abundant. It indicates that the Cockatoo Formation is of shallow marine origin and of Frasnian, possibly Fammenian age.

The Westwood Member of the Cockatoo Formation, a mid-Frasnian sequence of limestones, dolomites and interbedded sandstone, outcrops in the northwestern portion of the basin. With a measured thickness of 560m the Westwood Member is richly fossiliferous, containing stromatoporoids, algae, corals and oncolites, fish plates, etc. An interfingering lagoonal and back reef environment of deposition has been interpreted by Veevers (1969).

- Ningbing Limestone

A Late Devonian to Early Carboniferous reef complex outcrops extensively along the western basin margin. The reef complex has many similarities with the more extensive exposures of the northern Canning Basin, described in detail by Playford (1980).

In the Canning Basin, the age of the complex ranges from Frasnian (and possibly Givetian) to the Fammenian. In the Bonaprte Basin however, the Ningbing Limestone is of Fammenian to Tournaisian age.

In the southwestern and southeastern portions of the basin, a lagoonal facies is present, 350m thick, age equivalent to the basal Ningbing Limestone. Named the Buttons Beds, this unit is abundantly fossiliferous and often dark with a foetid odour on fresh surfaces. In Keep River No. 1 well, 1025m of dense biodolodismicrite, pelmicrite and intramicrite was drilled below 3712m.

The majority of this interval has been mapped as back reef and lagoonal facies, but with the interval 3712m to 3993m considered to be of reefal facies (Roberts & Veevers, 1973).

The Keep River No. 1 well was drilled on the Pincombe Ridge, a major northeast plunging intra basin paleohigh. The Pincombe Ridge is exposed at the surface as Proterozoic sandstones southwest of the well. Ningbing Limestone outcrops occur immediately to the north of the Precambrian exposures, suggesting that the Pincombe Ridge acted as a locus for reef growth. The presence in outcrop and the subsurface of thick Early Carboniferous (Tournaisian) back reef and shallow intratidal facies east of the Pincombe High strengthens the hypothesis that a barrier reef complex existed along the western margin of the High during the Late Devonian and Early Carboniferous.

- Keep River Group

For convenience, the Burt Range Formation, Enga Sandstone, Septimus Limestone and Zimmerman Sandstone are collectively referred to as the Keep River Group.

These conformable units outcrop in the Burt Range Syncline in the southeast Bonaparte Basin. Of Early Carboniferous (Tournaisian) age, they are cyclical in depositional style and range from near-shore sands to dark oolitic calcareous sands, sandy biopelsparites and fossiliferous calcarenites. The majority of the sequence has been interpreted to be of intra and supra tidal facies (Crow, 1980), and except for the absence of the Zimmerman Sandstone, has a maximum known thickness of 814m in Keep River No. 1 well.

Roberts and Veevers (1973) concluded from lithological evidence that reef growth probably ceased during the deposition of the Burt Range Formation. The lower two-thirds of the formation consists of back reef and interfingering lagoonal calcarenites, while the upper portion of the Burt Range formation is of non-reefal affinity. Younger units also appear to have little reefal tendency.

- Milligans Beds

Dark silty shales of the Early Carboniferous (Visean) Milligans Beds outcrop in the area near Spirit Hill No. 1 well, and underly much of the eastern portion of the basin.

The maximum known thickness was encountered in Keep River No. 1 where 2142m of shales, silts and thin sandstones were penetrated.

The Milligans Beds are erosionally disconformable on underlying units and contain an open marine fauna. The Milligans Beds are equivalent to the upper portion of the Bonaparte Beds. The lithologies are virtually identical, except that occasional thin gypsiferous and carbonate intervals in the Milligans Beds are suggestive of an estuarine environment of deposition (Crow, 1980).

- Bonaparte Beds

The Bonaparte Beds consist of a thick sequence of fossiliferous dark carbonaceous shales and silts known only from the subsurface, mainly in the eastern part of the basin (Bonaparte Nos. 1 and 2 wells).

- Tanmurra Formation

It was intersected by Keep River No. 1 well, where it consists of 276m of calcareous sandstones with minor shales.

- Late Carboniferous and Permian Sediments

They form the Weaber Range outcrop, and were intersected by Keep River No. 1. They consist mainly of sandstone (Kulshill Formation) unconformably overlying the Tanmurra Formation

2.2 Structure

The basin is divided into two sub-basins by the northeasterly trending Pincombe Ridge. The Carlton Sub-basin lies to the west of the Ridge, the Burt Range Syncline to the east. Field work and shallow drilling has shown that the Pincombe Ridge was in existence during the Devonian and Carboniferous, with sediments thinning onto the flanks of the paleohigh.

The Carlton Sub-basin is dominated by the thick fine marine clastics of the Bonaparte Beds. In the Burt Range Syncline, however, a thinner sequence of shallow marine carbonates and clastics has indicated that a broad shelf existed along the eastern basin margin. The likelihood that a major carbonate platform margin with an associated barrier reef complex was established on the Pincombe Ridge, has been discussed previously.

The eastern boundary of both the Halls Creek Mobile Zone and the Bonaparte Basin is formed by the Cockatoo Fault. Detailed investigation of the fault during mineral exploration has shown that the fault zone consists of an en-echelon "synthetic" strike-slip fault system with the individual faults trending approximately north-south (Noakes, 1977). The underlying force responsible is a major left-lateral wrench fault trending north-northeast.

Evidence also exists for the west-northwest oriented antithetic faults, especially in the area between the Keep River and Spirit Hill wells. The evidence includes a right-lateral shift to the axis of the Burt Range Syncline on seismic data, plus supporting airphoto and gravity information. The existence of other similar faults will be discussed in the interpretation section.

The major structural elements are summarised as Fig. 4.

2.3 Hydrocarbon Potential

2.3.1 Hydrocarbon Indications and Source Potential

In Keep River No. 1, a DST of the interval 2583m to 3353m over the lower Milligans Beds and upper Keep River Group flowed gas at 85000 cubic metres per day (3 MMCFGPD) reducing to 3400 cubic metres per day (0.12 MMCFGPD) after eight hours. Traces of oil were also noted in these sections and from cores of Ningbing Limestone in the same well.

In addition, numerous oil shows have been encountered in shallow mineral exploration core holes drilled around the basin margins, mainly from the Burt Range, Enga and Septimus Formations

An optical and geochemical study of the organic matter has been conducted on samples from the Bonaparte No. 2 well. The conclusions are that over the studied interval (500m-1800m) the Milligans Beds contain a mostly land-derived organic matter in good maturation stage (oil zone), with an average to fair gas potential. Comparison with other wells in the area tend to indicate that the margins of the basin would be more favourable to oil generation than its centre.

An average geothermal gradient of $3^{o}C/100m$ has been calculated using the results of the Bonaparte and Keep River wells, which would place the present top of the oil window near 2000m. The few laboratory analyses available have shown that a considerable amount of uplift and erosion must have occurred as the top of the oil window in the Late Carboniferous and Devonian sediment is now close to ground level.

2.3.2 Reservoir and Seal

From the information available at present, there are three possibilities of reservoir development in the area:

- Reef complexes of Ningbing age related to the Pincombe High, probably on the western flank (see "Ningbing Limestone" - 2.1.2), or to any other structural high in existence during the Devonian. The seal would be provided by surrounding compact carbonates, either Ningbing or Keep River Group, or alternatively, by the basinal shales of the Bonaparte Beds.

- Sandstone accumulations present in Milligans Beds, similar to the interbed which flowed gas at Keep River No. 1. They are more likely to develop in the lower members of the Milligans Beds, and/or close to the Pincombe Inlier itself. Seal would be provided by the Milligans Beds and southwest closure by the transverse faults which cut across the Pincombe axis.

- The Keep River Group may present either primary porosity presented in formations such as the Sandy Dolomite (Enga Sandstone), a secondary porosity developed either in calcareous sandstones or carbonates where they come into contact with the Milligans Beds. The mechanism for secondary porosity development would then be related to the dewatering of the black shales during compaction. The seal would be provided by the Milligan Beds.

Although porous in outcrop (e.g. near Kununurra), the Cockatoo Formation loses porosity at great depth as in Keep River No. 1 (4736m). However, it has not been intersected yet at intermediate depth and its reservoir capacities are therefore unknown.

2.4 Previous Geophysical Exploration

Previous seismic exploration in Permit OP 186 was mainly concentrated on the Pincombe High axis area (west of Keep River)and, to a lesser extent to the southern half of the permit (Burt Range Sub-basin).

A total of 886 km of seismic reflection data was acquired during various surveys conducted between 1962 and 1972; however, 61 km only were shot on the eastern margin of the basin (for refraction work, the corresponding figures would be 176 and 78). The data quality is generally poor, especially for the surveys shot before 1967. A complete review of the surveys' parameters and results was made by AAP in 1980 (3) as an attempt to select appropriate recording techniques and parameters for future work. One of the conclusions was to recommend the use of a surface source with a frequency input control.

Consequently, the Vibroseis source was selected when seismic exploration resumed in 1980. The BNT-80 Seismic Survey consisted of 141 km of 12-fold coverage data, mainly over the Pincombe High axis. It was designed, basically, to tie together the data from the previous surveys and check to what extent modern acquisition and processing techniques could bring improvement to the data. Unfortunately, the standard of data quality was little improved. One regional line shot across the eastern margin of the basin also showed very poor results.

From all the pre-1980 seismic coverage, the three surveys considered as most useful are:

- the Border Creek and Oakes Creek Surveys on the Pincombe High axis;
- the Burt Range Survey in the southern part of the Burt Range Basin.

At the present stage, approximately 20% and 60% respectively, of the Oakes Creek and Border Creek Surveys lines have been reprocessed in order to assist interpretation.

Several gravity surveys were conducted between 1962 and 1979 throughout the area, especially over the Pincombe High axis (Oakes Creek, Lone Hill and Cockatoo Surveys) and the eastern margin (Legune, Cockatoo Surveys).

In addition, gravity measurements were made along all the lines from the BNT-80 Survey, and a comprehensive grid was added at the same time over the eastern margin.

Due to the varying quality of surveying control, difficulties were experienced when matching the different sets of data. The B.M.R. is currently trying to solve these problems in order to produce a synthetic Bouguer anomaly map. An empirical comparison was made by AAP in 1980, and the results are interpreted and discussed in "OP 186 - Cockatoo Gravity Survey and Interpretation of Gravity Data" (3).

A low sensitivity aeromagnetic survey was conducted by Geometrics for Australian Aquitaine Minerals in 1974. The main magnetic marker is probably intra-Precambrian basement and the low level amplitude anomalies did not contribute much information. Some flows of Cambrian Antrim Plateau Volcanics associated with an E-W fault were interpreted to occur northwest of Legune Station and the possible occurrence of similar flows will be discussed in the interpretation section.

3. INTERPRETATION

3.1 Base Map Preparation

The base map had to integrate lines from five different surveys:

	System of Co-ordinates	Benchmarks used
Oakes Creek (1967)	Australian Geodetic Datum. UTM Zone 52. CM = 129°.	AAP BM1, AAP BM2, M60N.
Burt Range (1970)	Australian Geodetic Datum. CM= ?	P.W.D. 34.
Border Creek (1972)	Australian Geodetic Datum. CM= 129°.	AAP BM1.
BNT-80	Australian Geodetic Datum.	Weaber, Wicklow.
BNT-81	Australian Geodetic Datum.	AAP BM1, AAP BM3, M60N.

The different benchmarks have all been tied together; Weaber and Wicklow are first-order trig. stations to which AAP BM1, BM2 and M60N were tied in 1966 and 1967. Comparison with the UTM co-ordinates computed by Decca in 1981 proves that the same system was used for all the surveys. Only the "34" benchmark has not been checked (Burt Range Survey).

However, discrepancies occur when trying to match the different sets of data:

- the co-ordinates of three benchmarks from the Oakes Creek Survey were recomputed during the BNT-80 Survey and discrepancies varying from 120m to 210m were observed, as well as with the Keep River No. 1 well site;
- line BNT81-309, which was the actual continuation of line BNT80-204 in the field, plotted some 200m away on the map. A similar situation was observed with lines BNT81-304 and OC-11;
- a detailed gravity survey was conducted along most of the seismic lines by C.R.A. for mineral exploration late in 1981, within an area between lines BNT80-201, 207, 202 and 204. The survey was based on benchmarks M60N, AAP BM1 AND BM3 (co-ordinates revised by Decca) and was programmed to be performed according to the high quality standards necessary for this type of work (although some problems were reported by C.R.A.).

During the survey a number of permanent markers from the BNT-80 and 81 surveys were checked. The former showed discrepancies ranging from 70m to 200m in various directions, and the latter from 0m to 100m in a rather constant E-W direction.

As all co-ordinates were established in the same system, these problems must be attributed to a varying degree of surveying control. A thorough investigation would be required to solve them, including possibly a recheck in the field of several bench-marks from Oakes Creek and Border Creek surveys. Before that, and considering what is actually needed for the interpretation, it seemed sufficient to

- take the BNT-81 location map as a reference,
- tie the BNT-80 survey to it,
- transfer the other surveys without corrections.

The C.R.A. suvey is probably the most accurate of all, as was proven when the permanent marker at the intersection of lines BNT80-204 and 207 was rechecked during the establishment of the Weaber No. 1 well site co-ordinates. The results were in perfect agreement with the C.R.A. data; fitted reasonably well with Horizon's (24m), but showed a 150m (minimum) discrepancy with Austral United's. However, the observed differences between the C.R.A. and BWA-81 surveys were reasonably small and constant enough to justify the choice of the latter as the reference. On the other hand, the surveying control of the BNT-80 survey was known to be questionable.

- The two stations used (Weaber and Wicklow), although being first order trig.stations, are widely separated, which made intermediate traverse error-prone.
- Sun observations were carried out only once during the survey, which provides for control over the declination of the theodolite. Actually, one bearing was checked again in 1981 and was found wrong by more than one degree. Adjustment of the BNT-80 data to the BNT-81 grid was therefore achieved in the following way = the co-ordinates of the permanent markers listed below were extracted from the C.R.A. data files.

All these points were plotted on the 1:50,000 basemap produced for the BNT-81 survey and the BNT-80 grid was superimposed with the best possible match for all the points. This resulted in rotating the BNT-80 grid by about 1 degree, clockwise around a centre of rotation approximately defined by Long.129°E/ Lat.15°20'S. The reference points used were the following:

Intersection of line BNT80-201 with line BNT80-202
BC4
BC6
BNT80-204

Intersection of line BNT80-203 with line BNT80-202
BC4
BC6
BNT80-204

Intersection of line BNT80-205 with line BNT80-202
BC4
BC6
BNT80-204

Intersection of line BNT80-207 with line BNT80-202
BNT80-204

However, it is strongly stressed that the establishment of a more reliable basemap is necessary and will require a less empirical approach. The suggested method would consist of positioning all the lines on a semi-controlled photomosaic. The co-ordinates for each line intersection would be calculated, and co-ordinates for each shotpoint would be interpolated.

3.2 Data Quality

The changes of data quality noted along the BNT-81 lines are quite consistent with the pattern previously observed. A quality evaluation map was produced which integrates the new lines (Pl.2); it shows the same distribution of fair and poor quality data although a slight improvement exists in the Pincombe South area, on close inspection of the lines.

The correlation which was previously observed between the higher elevation and poor results zones is generally confirmed over the Pincombe High (west of the Keep River) where the 20m elevation contour has been drafted on the map. This supports the concept of the quality deterioration being due to the occurrence of sandstone ridges, which are themselves, possibly related with tectonic events.

No such correlation could be found for the Weaber grid, entirely situated over a flat black soil area. It may be assumed that sandstone ridges exist at shallow depth without any surface expression, or that poor quality is entirely due to faulting. The results of the Weaber No. 1 sonic log in the shallow part of the well may clarify the problem.

3.3 Results

Due to the generally poor data quality, no marker could be picked over the entire grid. Three distinct areas were studied, and only one marker in each one was mapped.

3.3.1 The South Pincombe Area (Pl.3)

Only one marker can be seen on most of the lines in the South Pincombe area (lines BC4 and 6 being the exception). Although very discontinuous, it shows as a strong amplitude reflector where visible. The vague structural indications that may be seen elsewhere in the section suggest it is a major unconformity with the overlying formations seeming to onlap onto it and it generally is unconformable with the underlying formations. This favours its identification as the top of the eroded Precambrian basement - within which reflections are likely to exist - transgressed by the late members of the Carboniferous Milligans Beds. Plate 3 may therefore be considered as an updated version of the Horizon F map included in the BNT-80 survey Interpretation Report (1).

The correlation with the outcrops of the Precambrian Pincombe Range is an additional confirmation. Figure 5 clearly indicates that the fault system is consistent with the one observed in the Range, as opposed to the more recent pattern which affects the Weaber Range. Moreover, the present topography of the Pincombe Range is quite consistent with the one suggested on Plate 3 - the faults have cut the Precambrian block into valleys and ridges trending SSW-NNE.

The prospects which could exist in such a configuration would be related either to deposition of sands in the valleys during the erosion phase, with subsequent sealing by the black shales, or carbonate buildups in a shallow marine environment. The seismic cannot give any indication about the former. Some anomalies on lines 301 and 303 could possibly be interpreted as carbonate buildups; however, their interpretation as eroded horst blocks (as presented on Pl.3) is much more consistent with the structural content.

3.2.2 North Pincombe Area (Plates 4 to 7)

The results of the BNT-81 survey are especially disappointing in the North Pincombe area. Most of the markers proved to be extremely discontinuous along the lines and inconsistent from one line to the other.

On the new lines, however, an unconformity has been tentatively picked - called the "green" marker. Through reference to the Keep River well (across a no-results zone) and typical patterns observed on lines OC-8 and OC-10, it may correspond to near the top of the Keep River Group (i.e. Septimus Formation). The unconformity with the overlying formation is mainly visible on line OC-8.

The main features of the contour map (Pl.4) are a high and low axis whose orientation (SSW-NNE) is consistent with the Pincombe High structural trends. However, they appear to be due to erosion rather than structuration.

However, picking problems occurred as the marker locally appears as an unconformity within the Milligans Beds which could not be properly controlled with the quality of the existing lines. The map shows that the black shales were deposited rather conformably with the green marker on the downthrown side of the fault, where the high and low axis are still present. On the upthrown side, however, nothing similar is observed and the channel is entirely filled, probably due to a different currents pattern at the time of deposition. A slight rollover can be observed along the fault, especially on line OC3, which suggests some horizontal displacement.

The prospectivity of the area can be reviewed as follows:

- Green marker = if its identification as top of the Keep River Group is correct, reservoirs may exist at this level and seal would be provided by the Carboniferous black shales. However, the structural control is not sufficient to mature a prospect and no closure is proven on the contour map.
- Light blue marker = this marker lies within the Ningbing/Keep River Group interval, where reservoirs may be present. Seismic anomalies could suggest favourable depositional features. However:-
  1) a good quality seismic grid would be needed to investigate their reliability and spatial distribution;
  2) horizontal and vertical seal would be a problem and would rely mainly on permeability-porosity variation within the Ningbing-Keep River Group.
- Carboniferous shales (blue marker) = no structural closure exists on the contour map, and the poor seismic quality is inadequate for possible interval pinchouts.

- The occurrence of a reservoir at the level of the purple marker entirely depends on its identification as a geological formation.

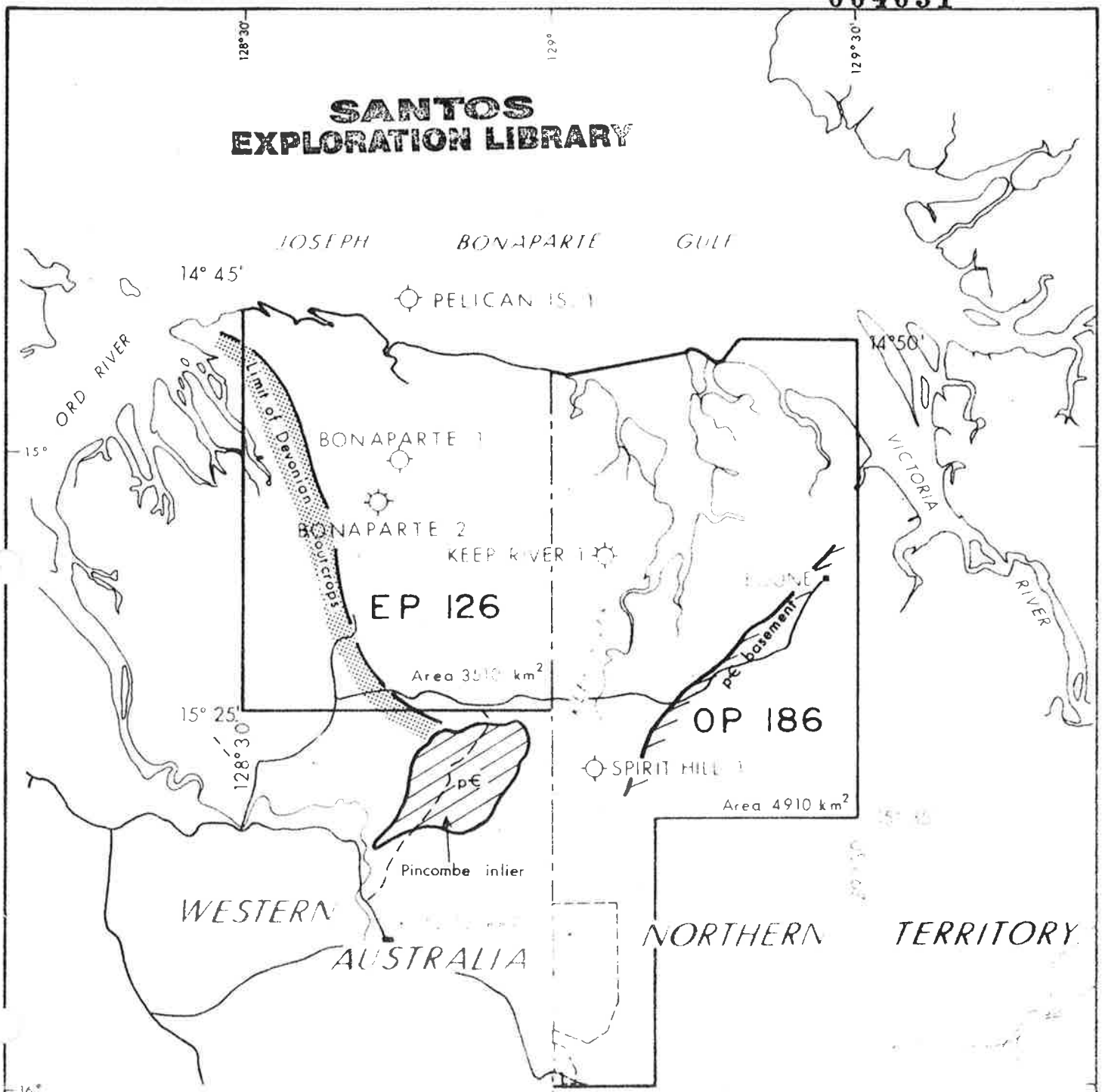
The proposed location for the Weaber No. 1 well is near the highest point on the structure, and close to a fault which might have fractured the formation and created permeability.

REFERENCES

1. OP 186/BNT-80 Seismic Survey Interpretation Report: G. Magnien, June 1981.

2. The Petroleum Geology of the Bonaparte Gulf Basin: R.A. Laws, 1981 (A.P.E.A. Conference, Adelaide).

3. OP 186 - A Review of Reflection Seismic Data: G. Magnien, 1980.



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ONSHORE BONAPARTE GULF BASIN

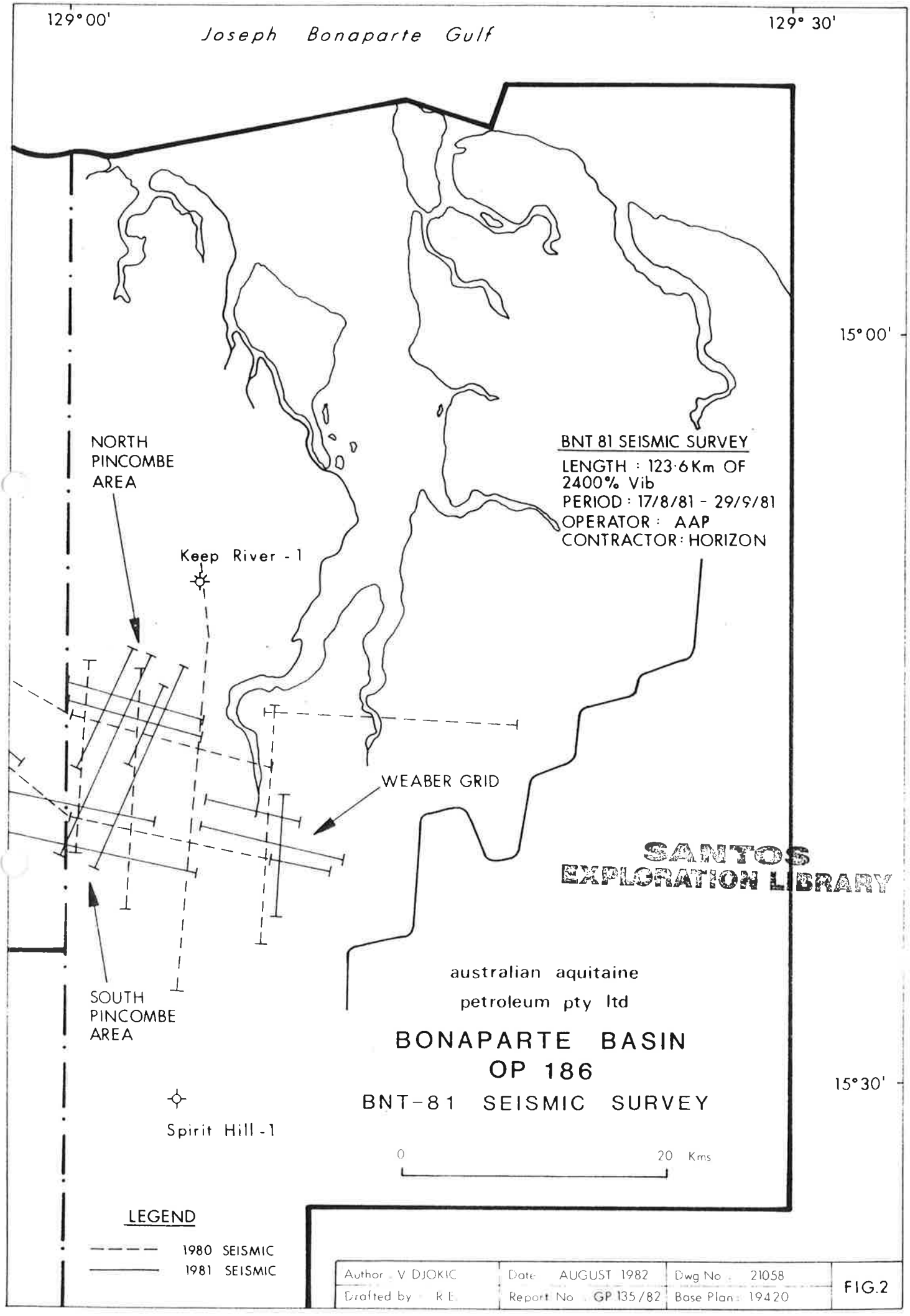
EP 126 / OP 186
LOCATION MAP

SCALE 1:1 000 000

0 10 20 40 60 80 100 Kms

---- NATIONAL PARK BOUNDARY

Author: B. LAWS	Date: SEPTEMBER 1980	Dwg No.: 19187	FIG. 1
Drafting: J.L.	Report No.: GP 135/136/82	Base Plan: 17204	



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BONAPARTE BASIN
OP 186
BNT-81 SEISMIC SURVEY

15°30'

Author : V DJOKIC	Date : AUGUST 1982	Dwg No : 21058	FIG.2
Drafted by : K E.	Report No : GP 135/82	Base Plan : 19420	

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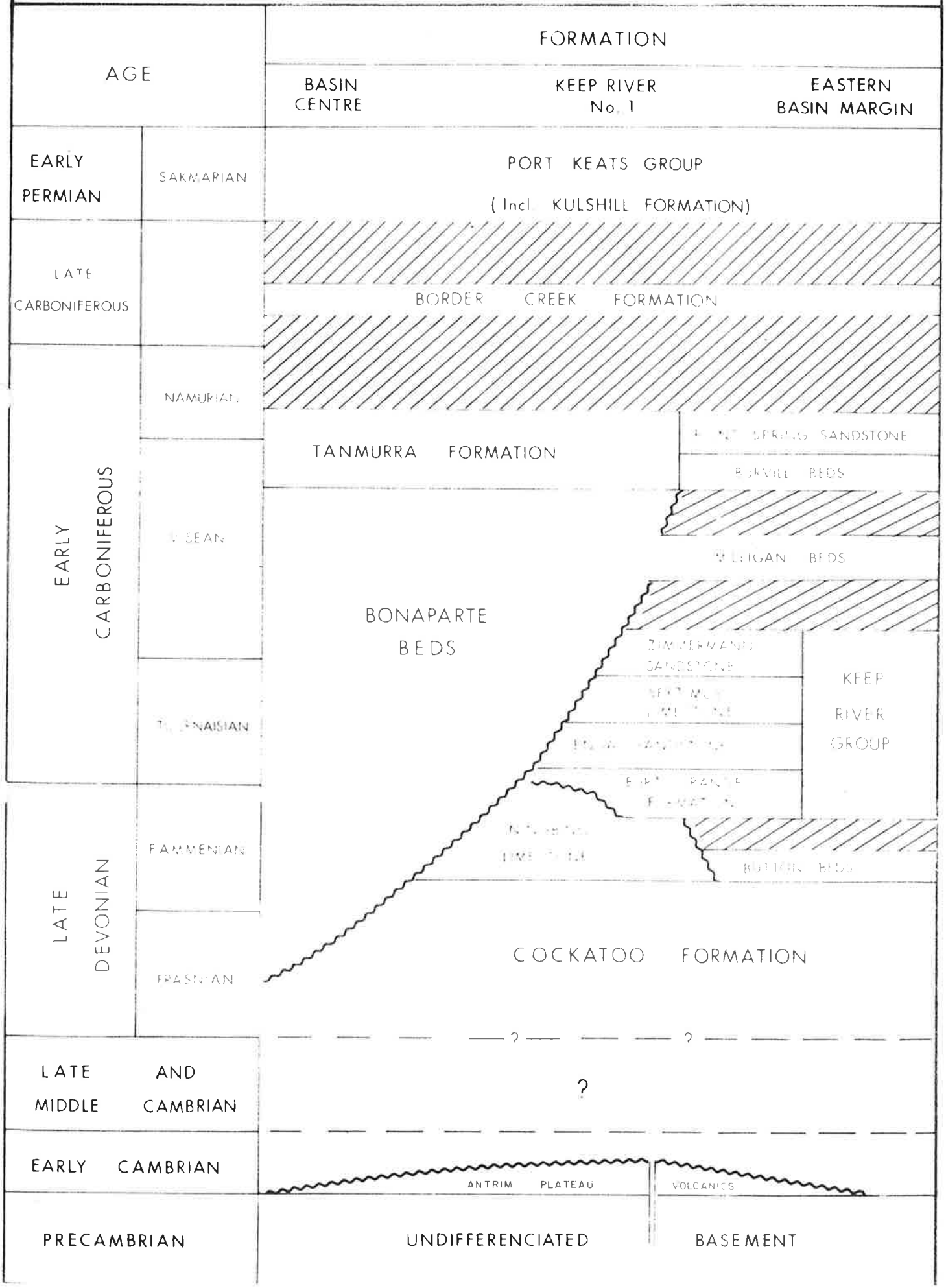
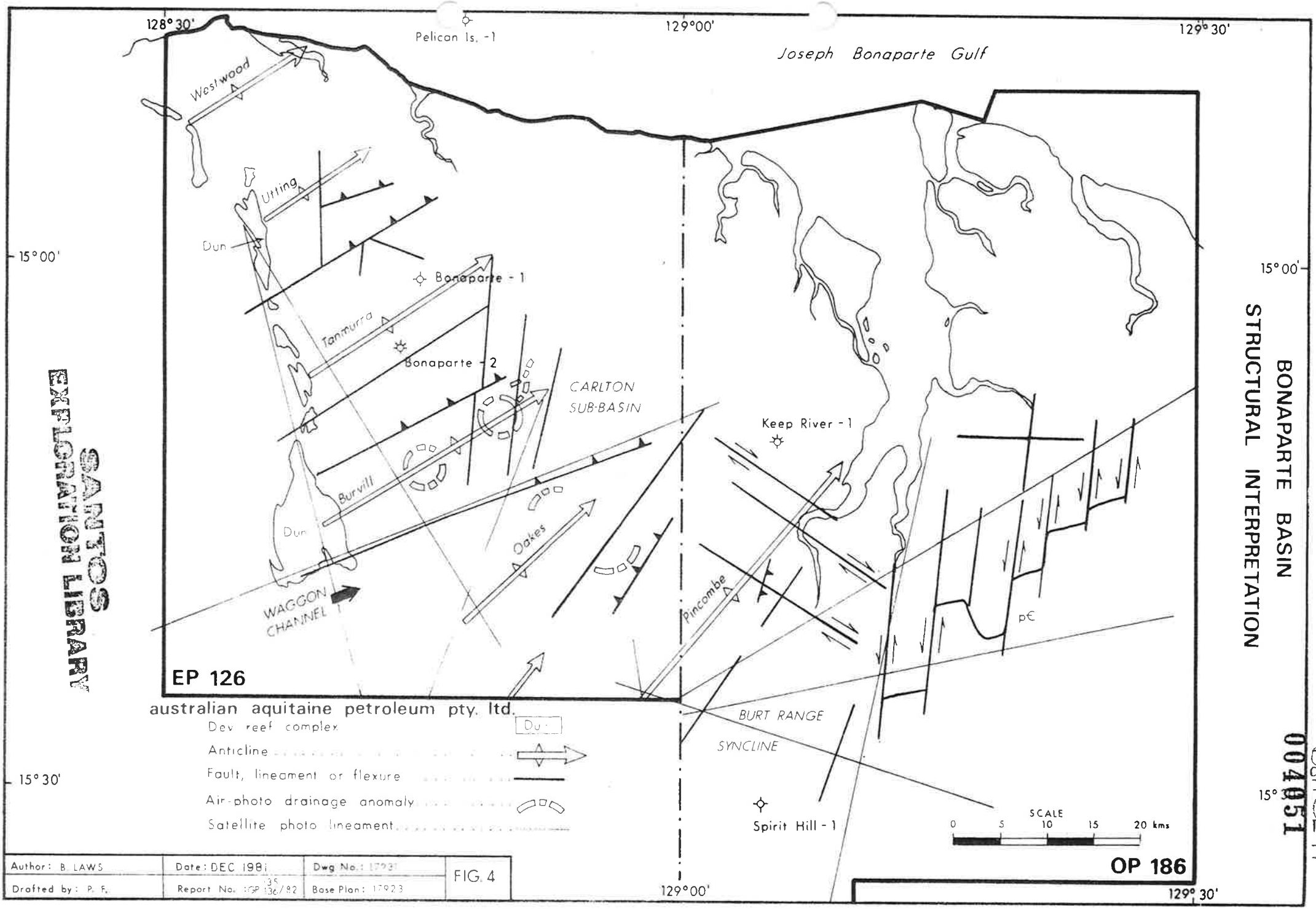
OP 186
Bonaparte Gulf Basin

004051

STRATIGRAPHIC TABLE





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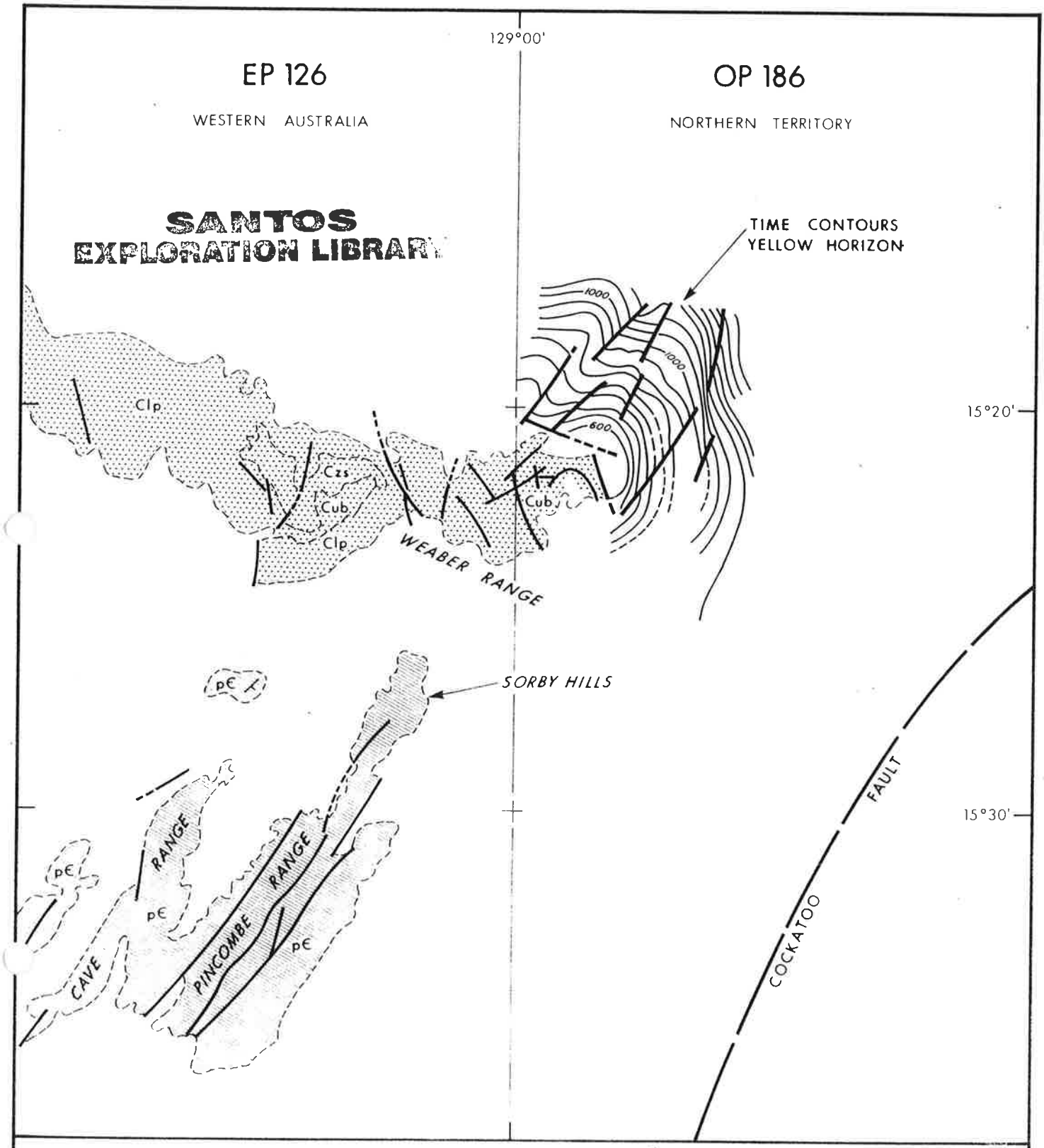
Author: B. LAWS	Date: DEC 1981	Dwg No.: 17931	FIG. 4
Drafted by: P. F.	Report No.: GP 135/82	Base Plan: 17923	



LEGEND

- pE — Pincombe Range Precambrian Outcrops
- Weaber Range Upper Carboniferous Outcrops
- 600 — BNT-81 Seismic Survey Interpretation

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Bonaparte Gulf Basin

Pincombe Trend

GEOLOGICAL and STRUCTURAL SKETCH MAP

SCALE 1:250 000

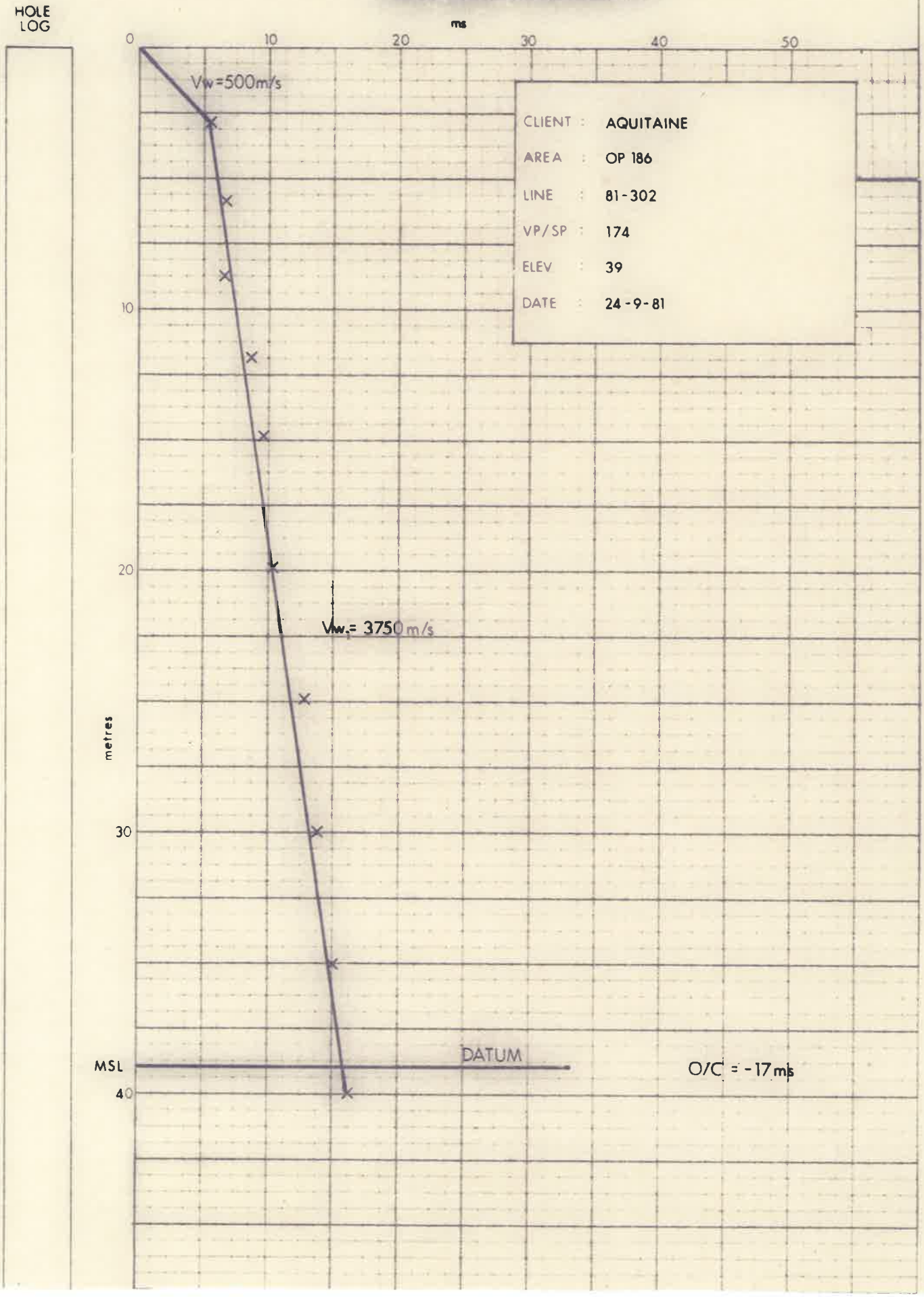
From VEEVERS & ROBERTS

Author: G. MAGNIEN	Date: OCTOBER 1982	Dwg. No.: 21176	FIG.5
Drafted by: J.H.	Report No.: GP/135/82	Base Plan:	

PR82/78

FIG. 6a

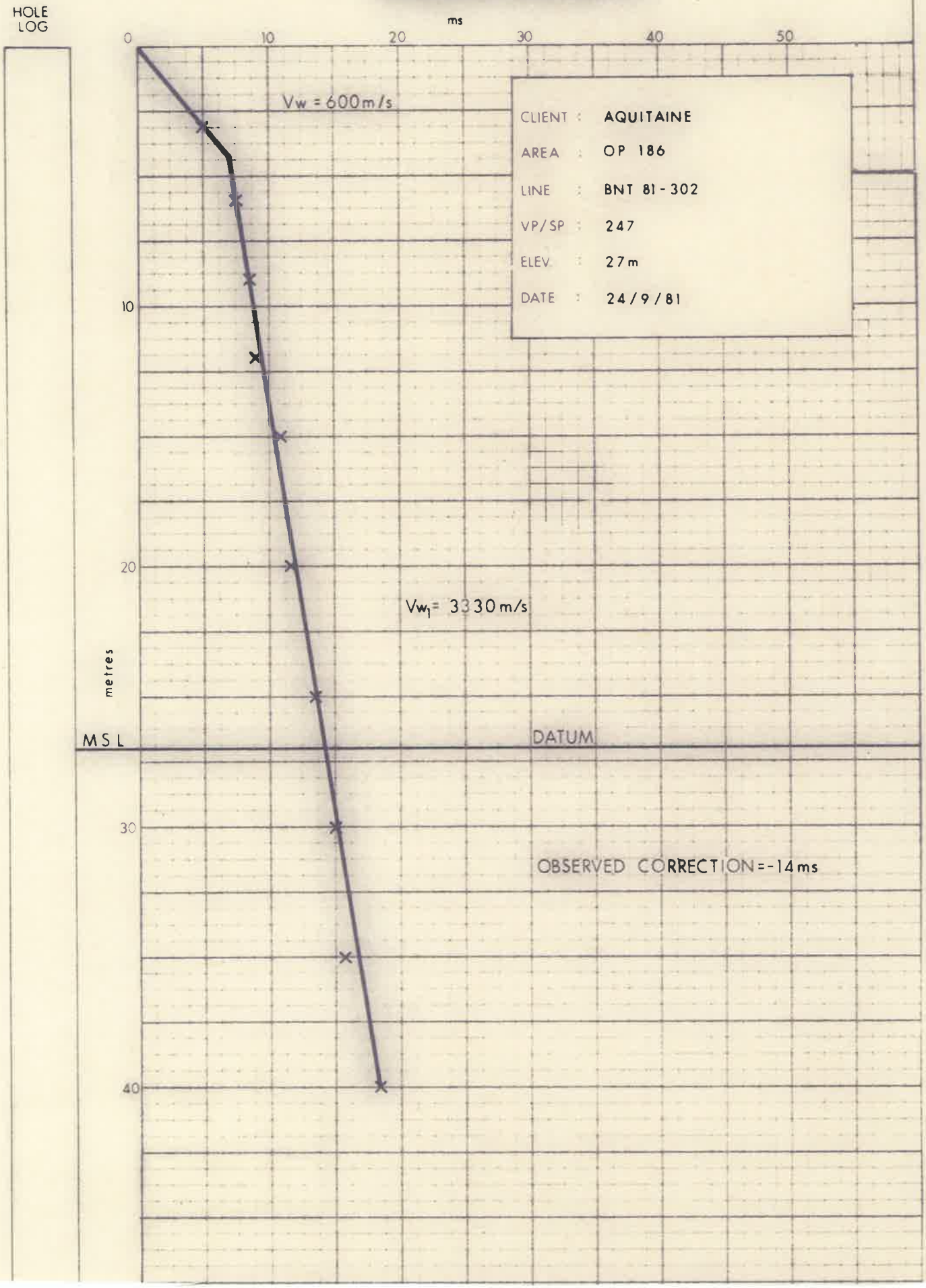
UPHOLE VELOCITY SURVEY



PR82/78

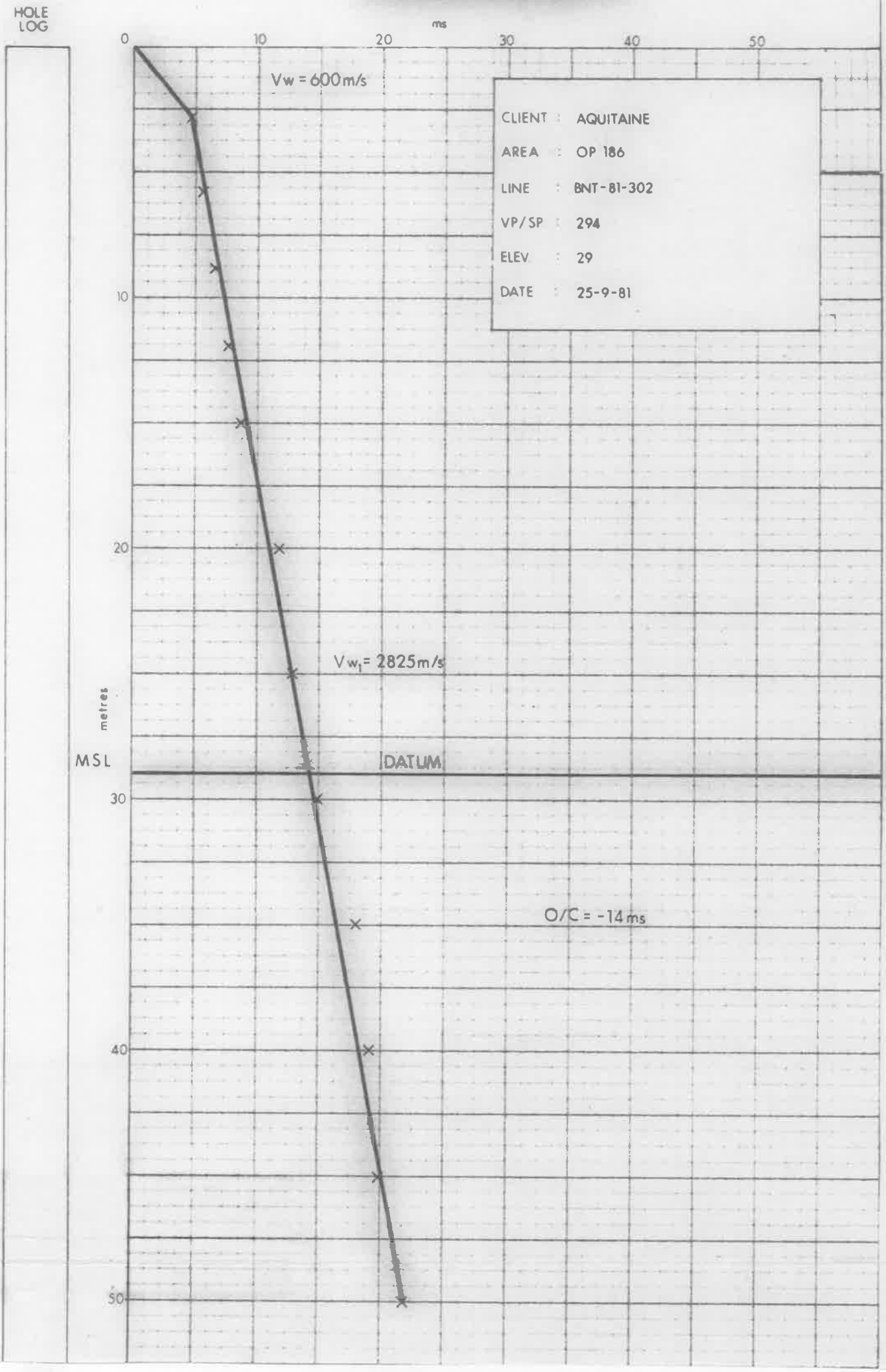
FIG.6b

UPHOLE VELOCITY SURVEY



PR82/78

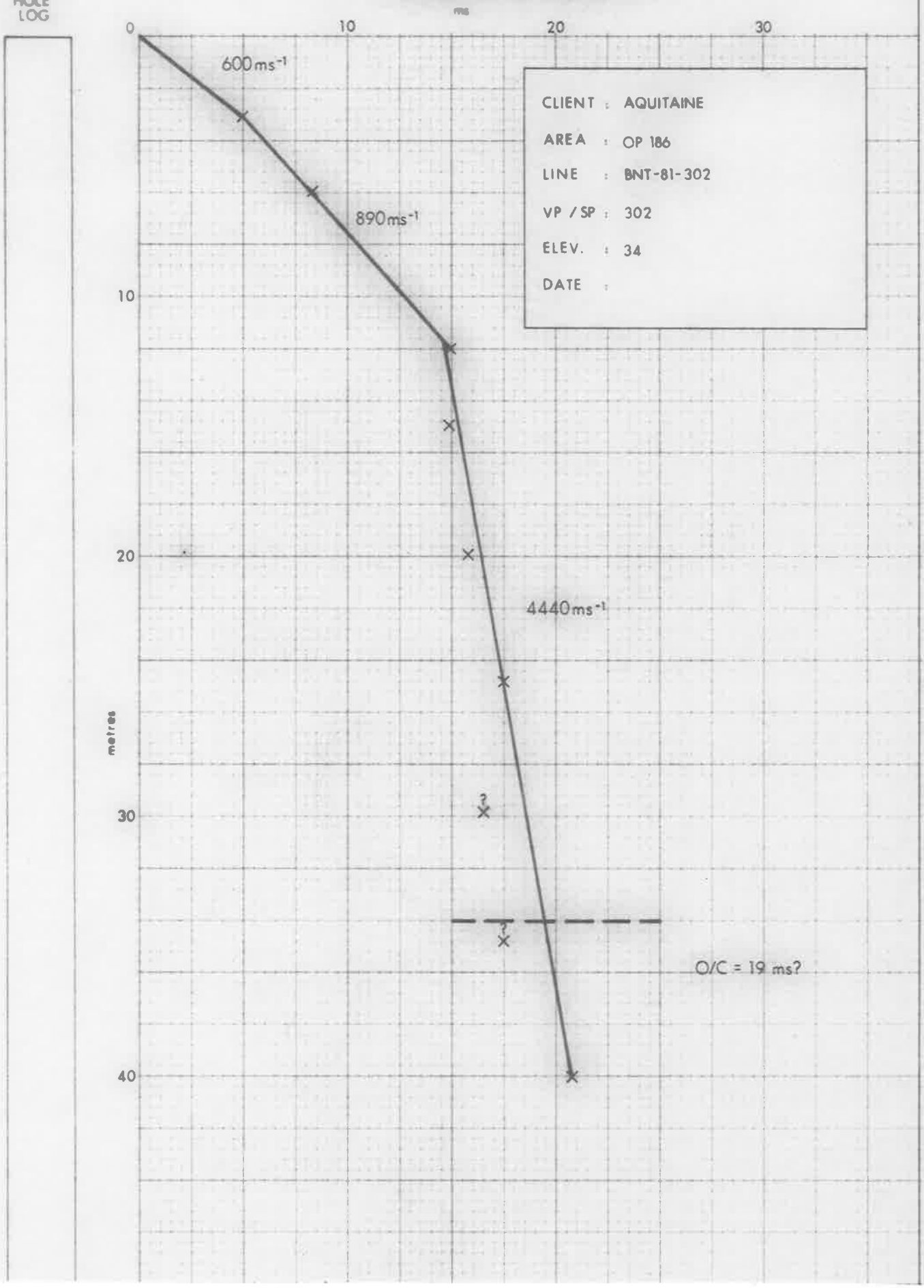
UPHOLE VELOCITY SURVEY



PR82/78

FIG. 6d

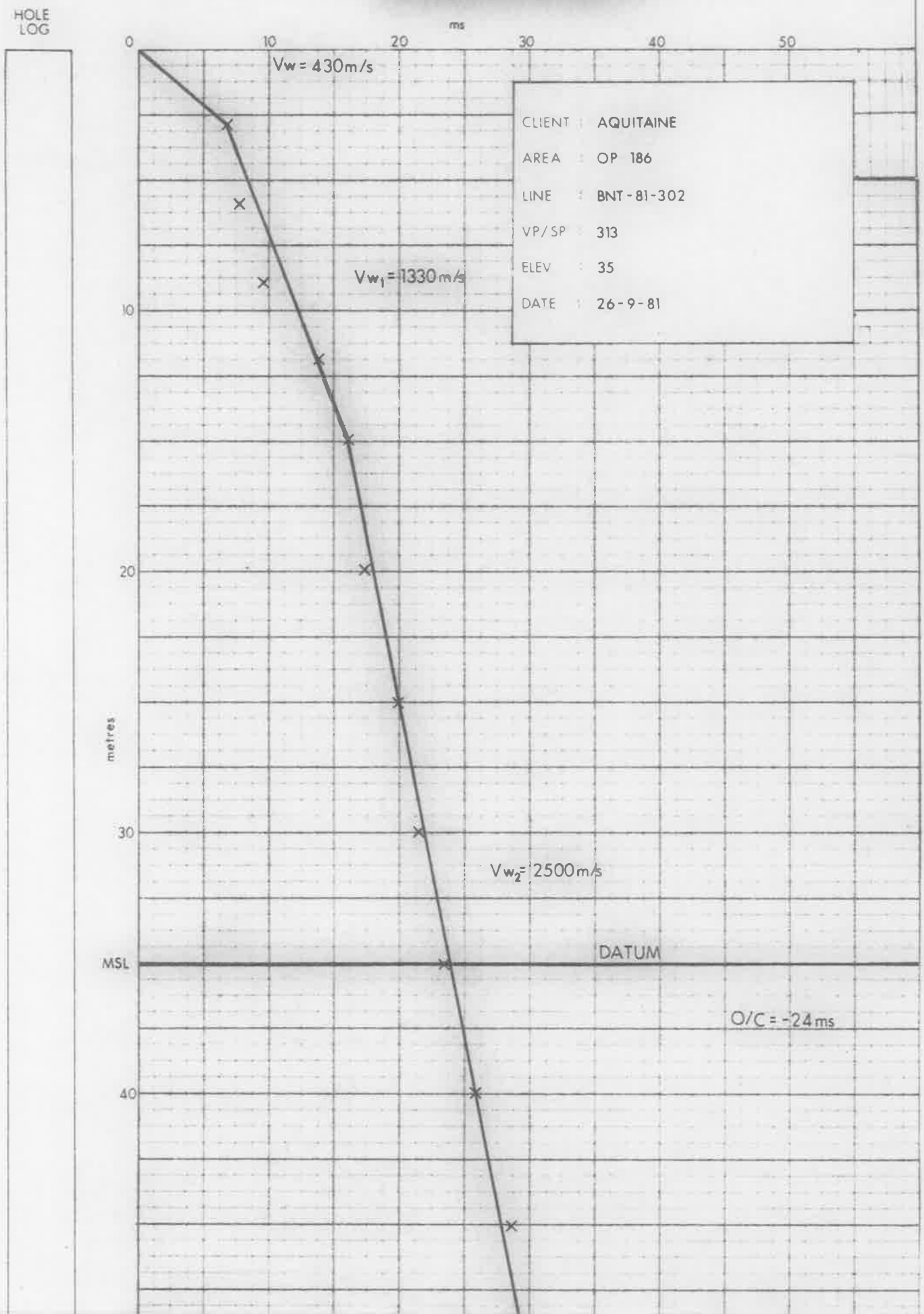
UPHOLE VELOCITY SURVEY



PR82/78

FIG. 6e

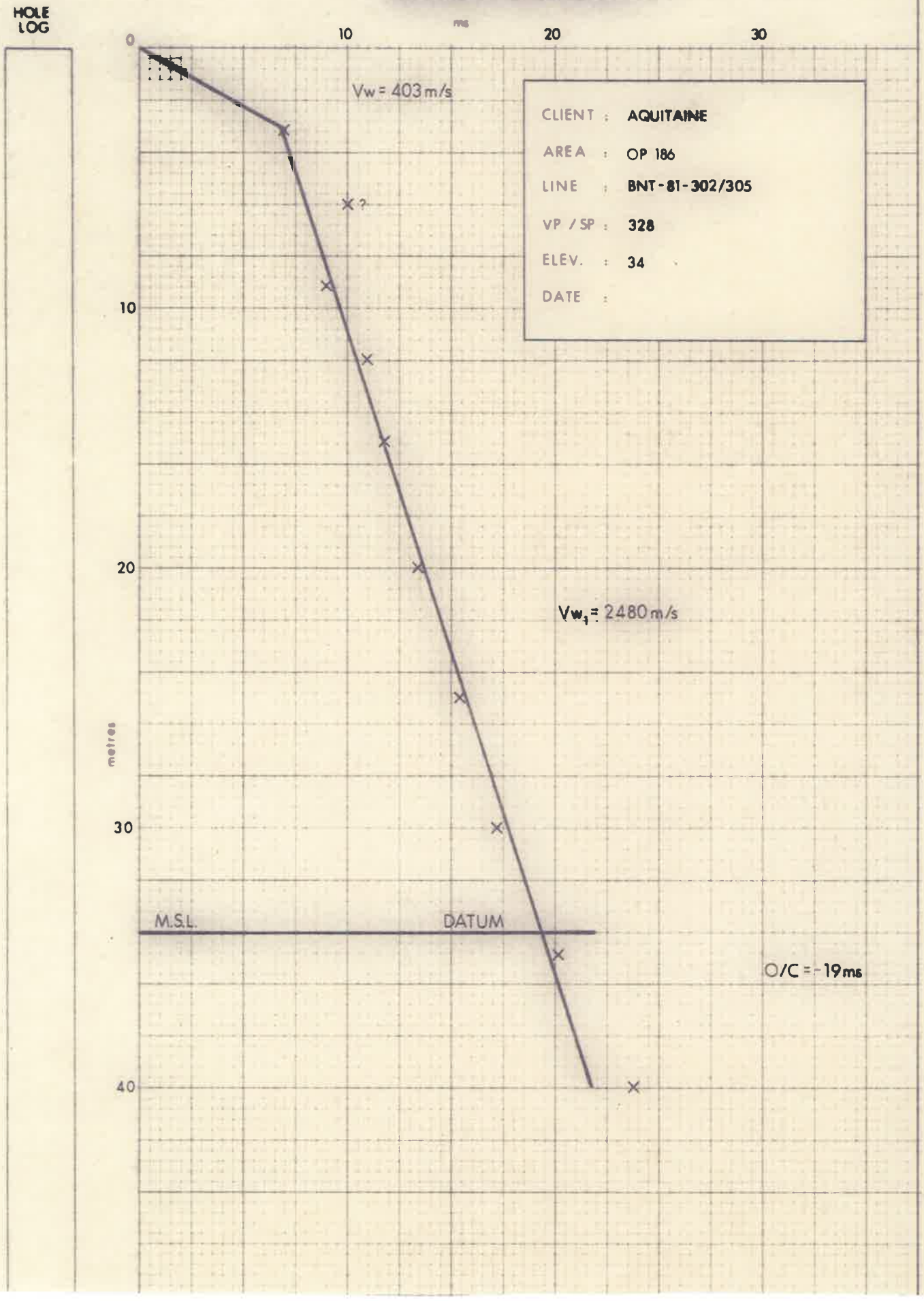
UPHOLE VELOCITY SURVEY



PR82/78

FIG.6f

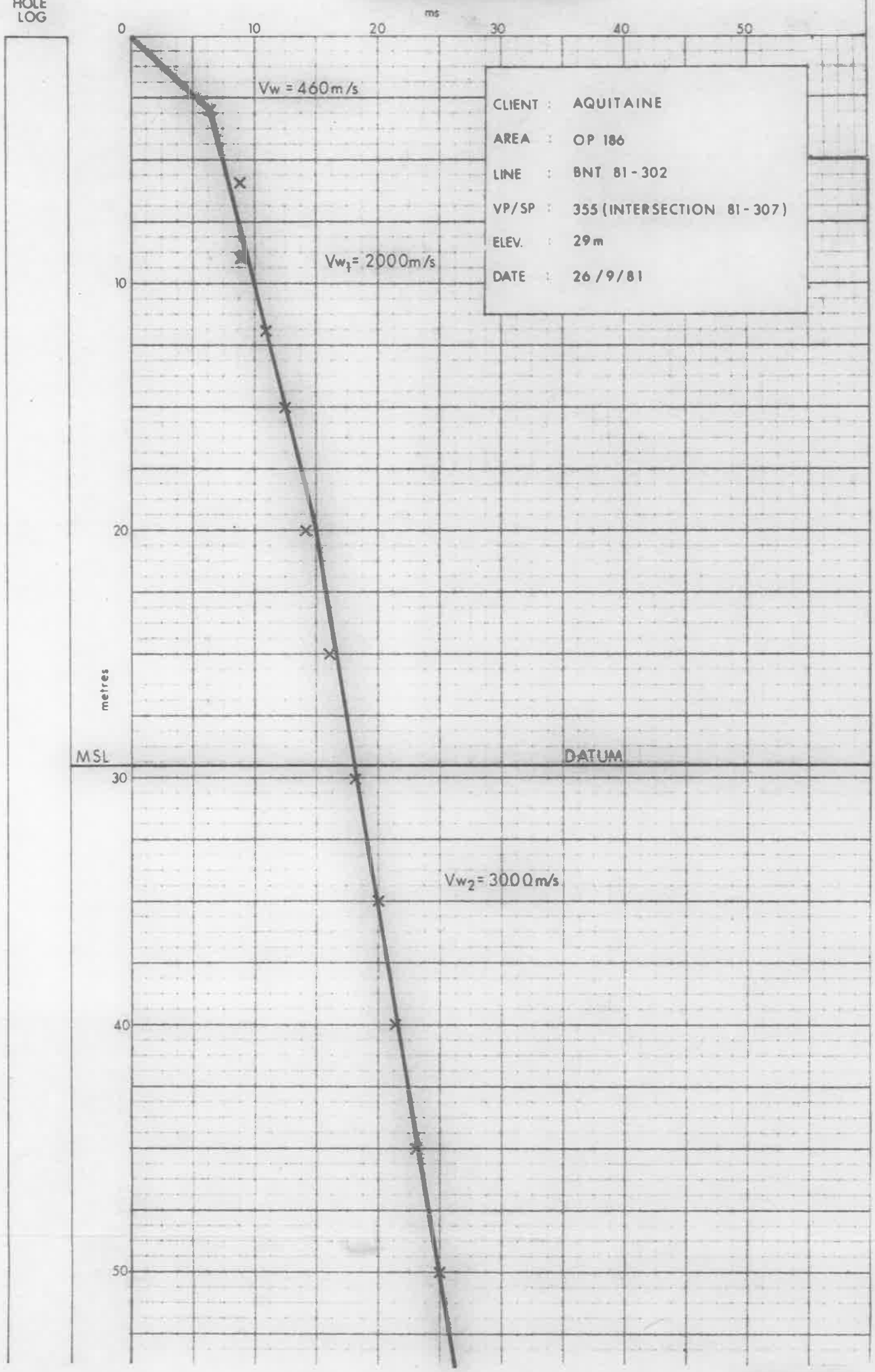
UPHOLE VELOCITY SURVEY



PR82/78

FIG. 6g

UPHOLE VELOCITY SURVEY

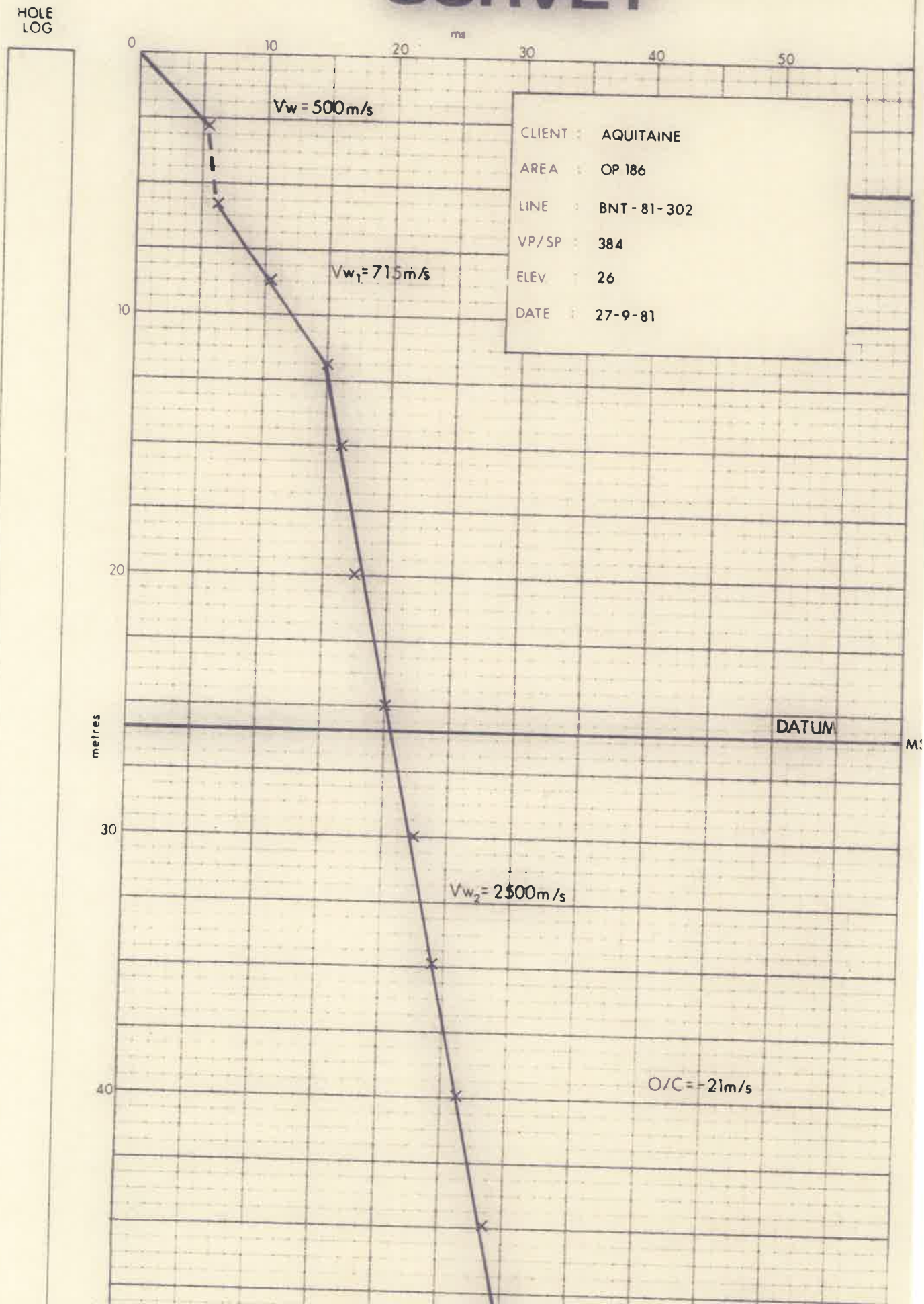


Dwg. No. 20567

PRSR/78

FIG. 6h

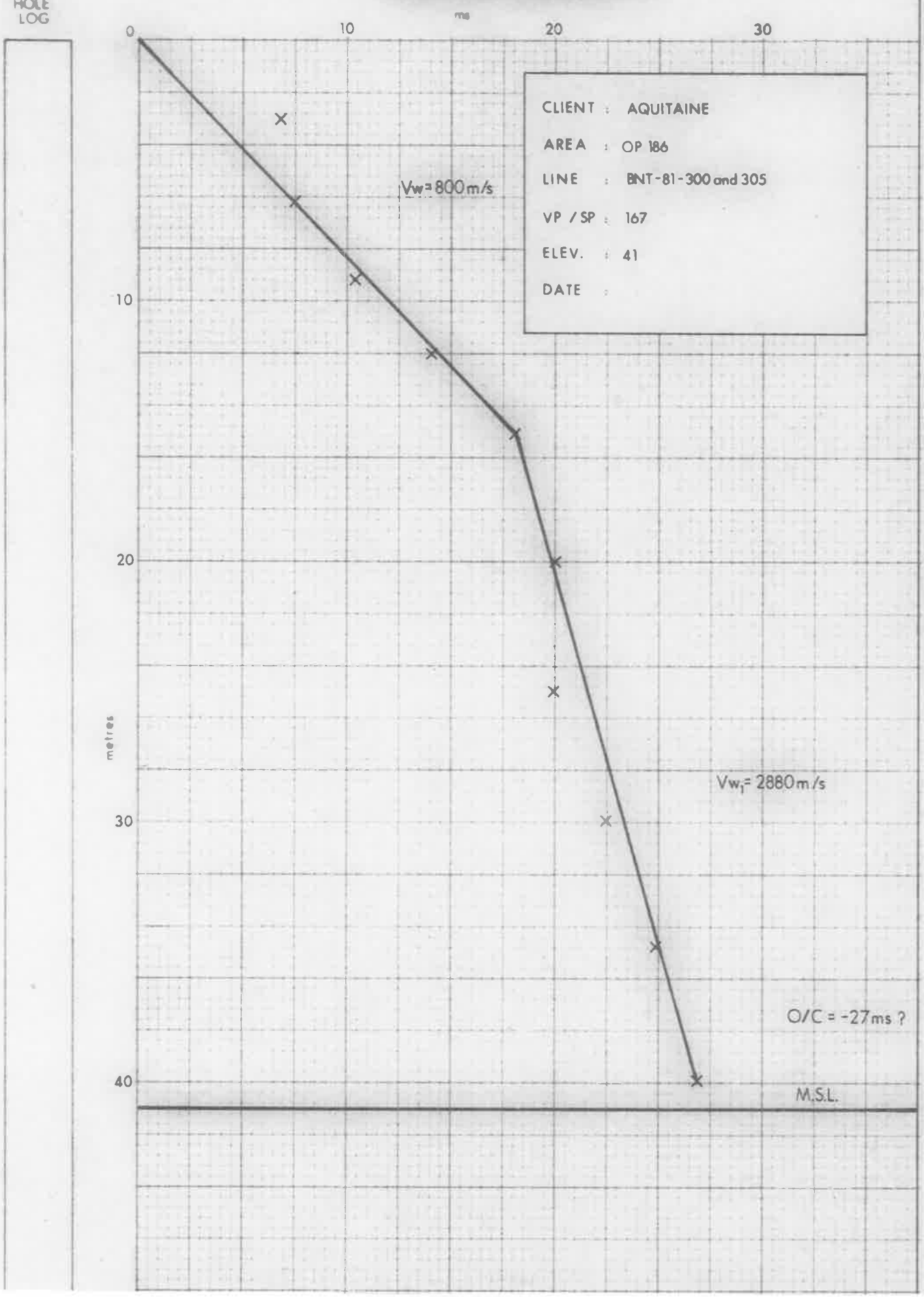
UPHOLE VELOCITY SURVEY



PR82/78

FIG.6i

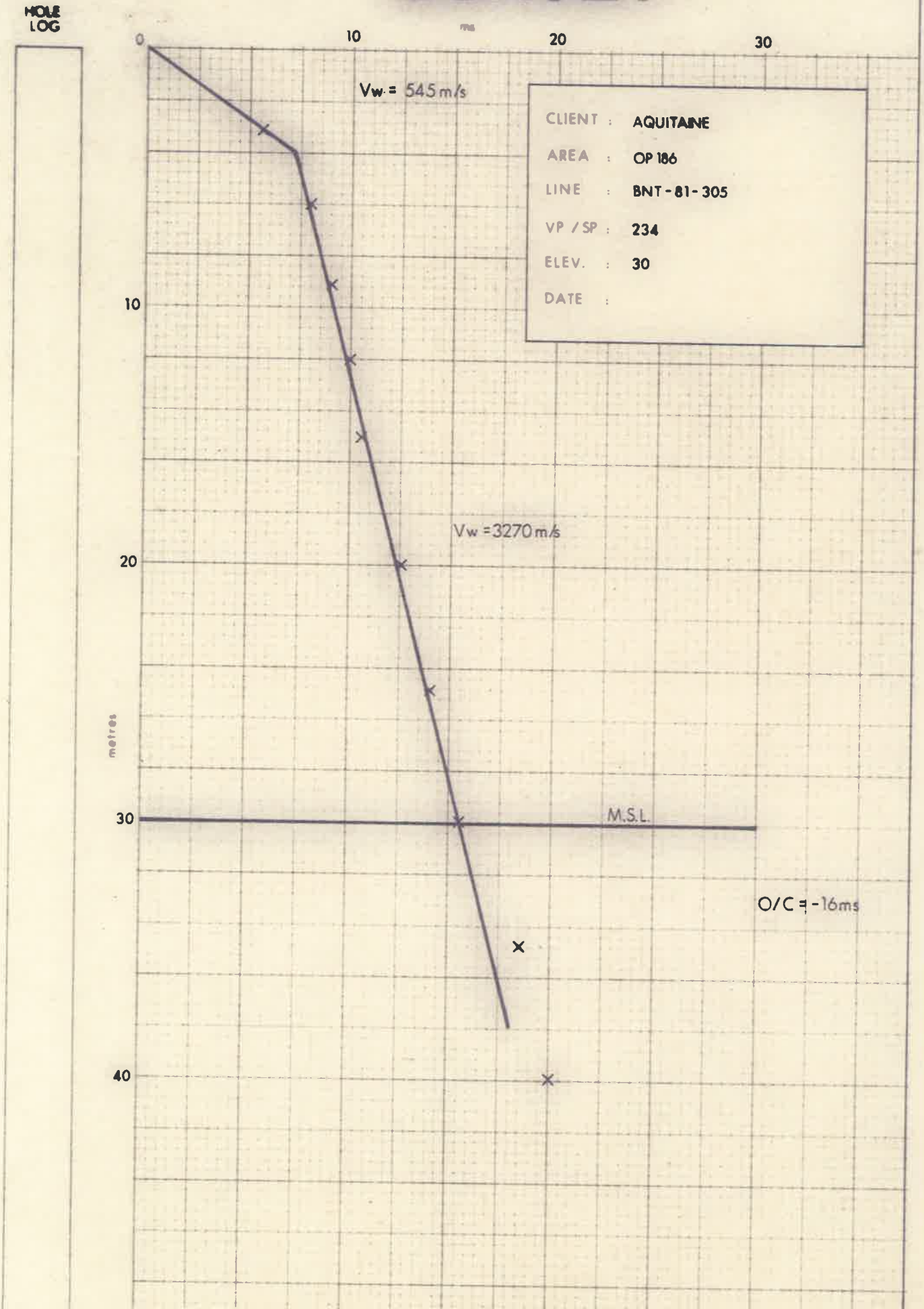
UPHOLE VELOCITY SURVEY



PR82/78

FIG. 6j

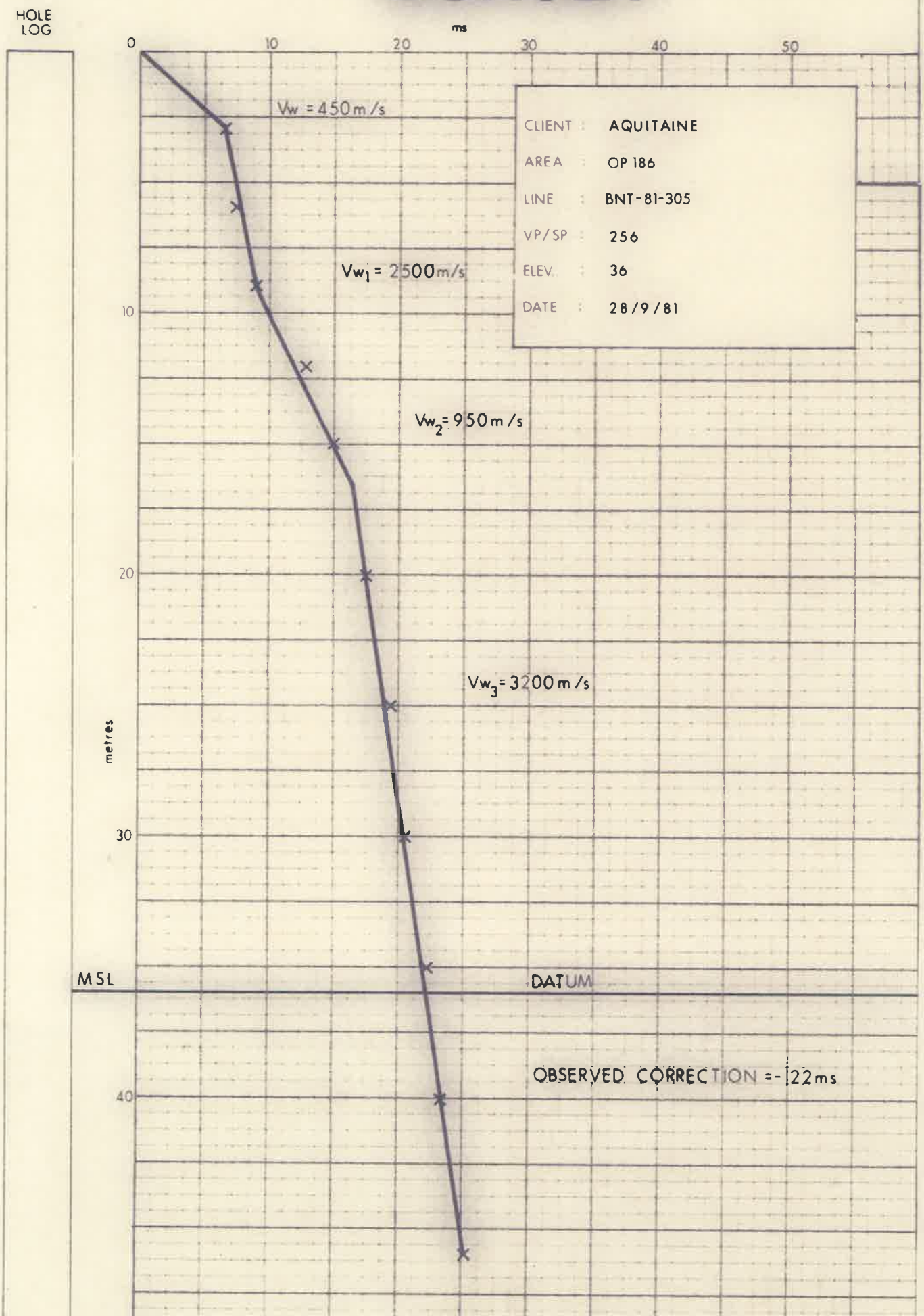
UPHOLE VELOCITY SURVEY



PR82/78

FIG. 6k

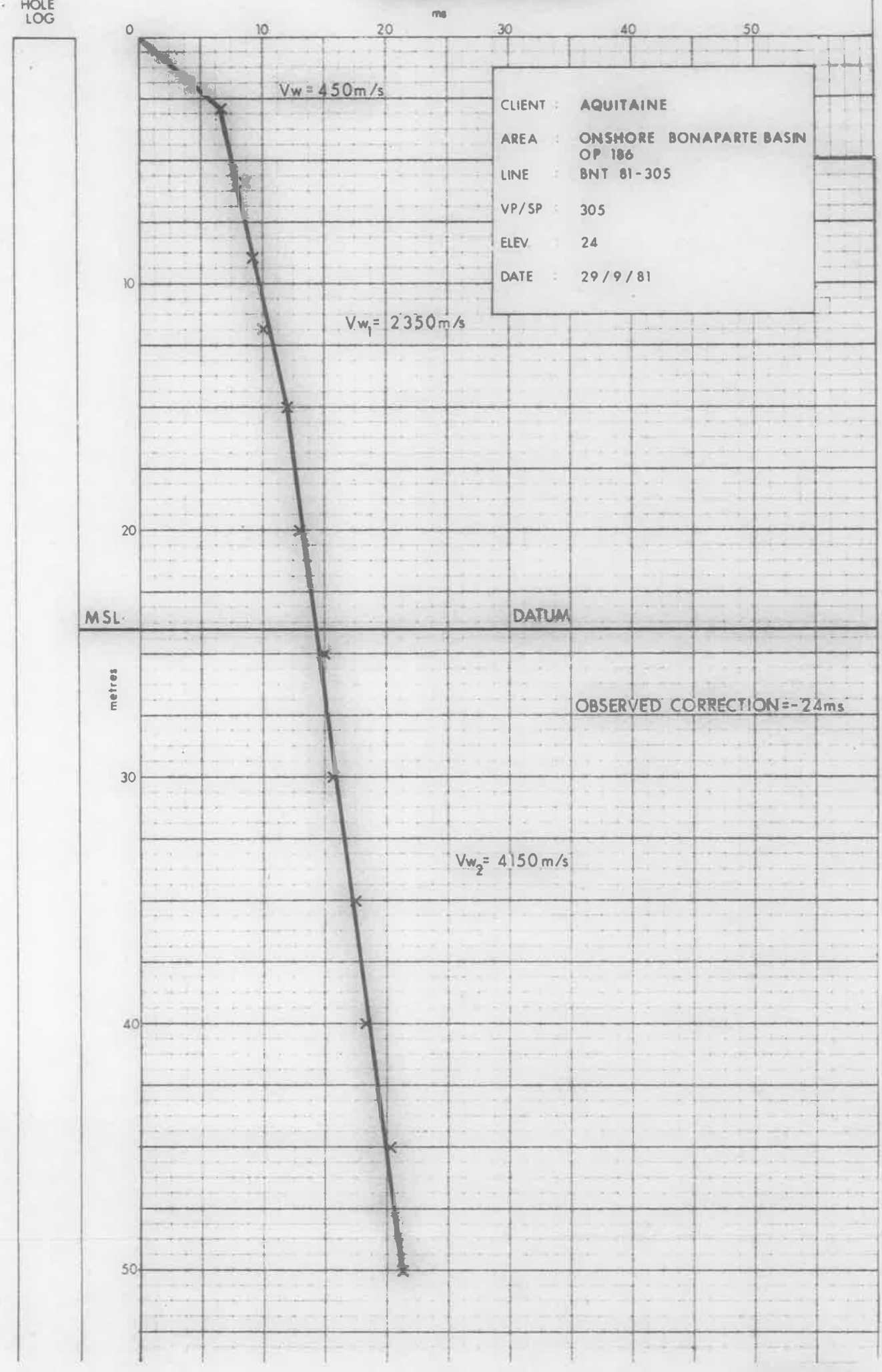
UPHOLE VELOCITY SURVEY



PR82/78

FIG. 6L

UPHOLE VELOCITY SURVEY

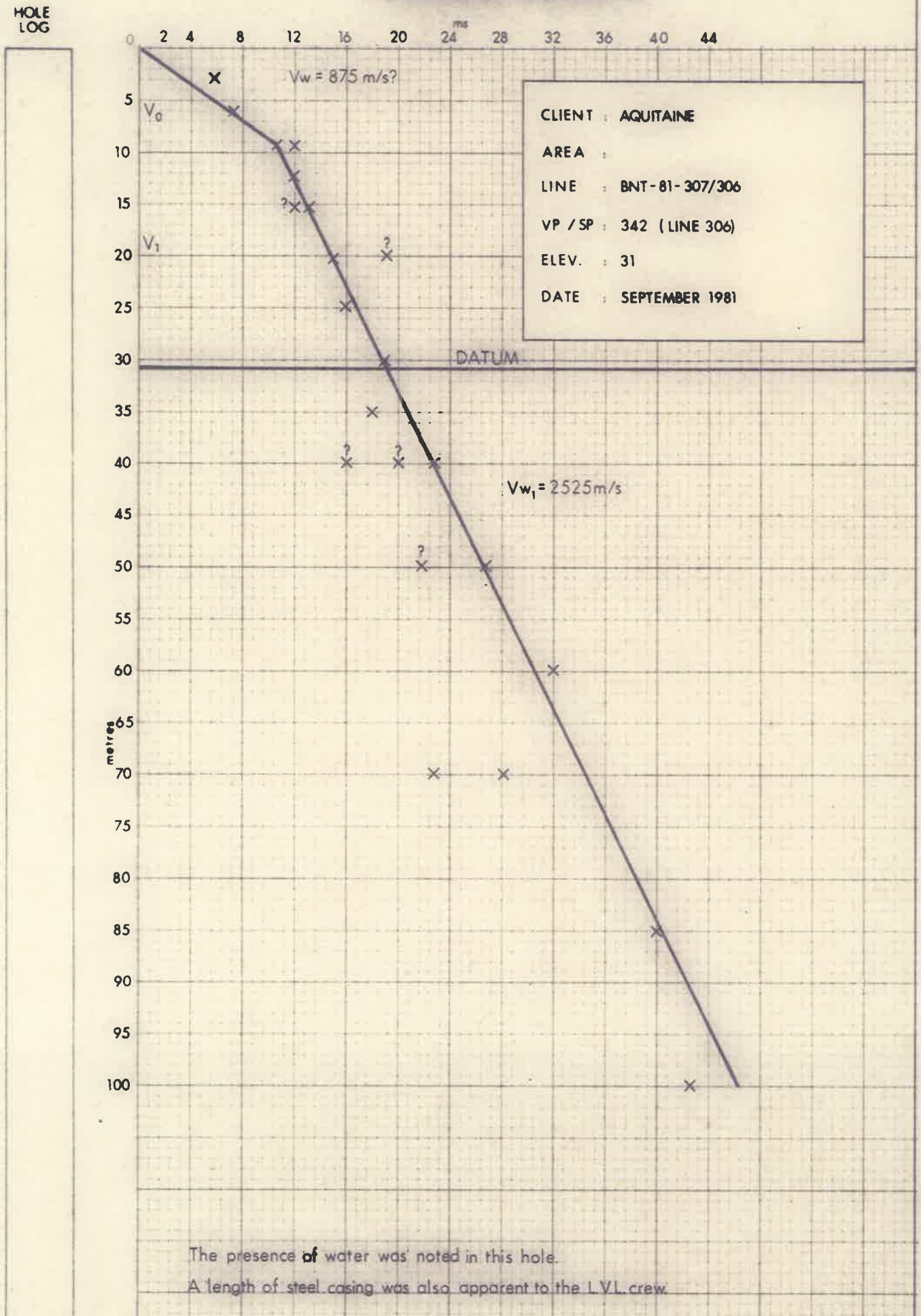


Dwg. No. 20569

PR82/78

FIG. 6m

UPHOLE VELOCITY SURVEY



The presence of water was noted in this hole.

A length of steel casing was also apparent to the L.V.L. crew.

AR82/78

FIG.6n

UPHOLE VELOCITY SURVEY