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PETROLOGICAL STUDY OF DURAL SOUTH (SHELL) No. 1 WELL, SYDNEY BASIN,

NEW SOUTH WALES

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P.J. HAWKINS and S. OZIMIC

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Petrological Study of Dural South (Shell) No. 1 Well, Sydney Basin, New South Wales.

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ABSTRACT

Twenty five lithological units were recognised and described in detail during the petrological study of cuttings and cores. It has been possible to group genetically related units whose sediments characterize a particular type of environment and provenance. A system of informal nomenclature has been used but the broad stratigraphy is similar to that recognised by Shell Development (Australia) Pty. Ltd. (1962). The study re-affirmed earlier reports that the source and reservoir characteristics of the sediments drilled in Dural South No. 1 Well are unfavourable for the generation and local accumulation of hydrocarbons.

GENERAL INFORMATION.

Well Data:

Official Name, No.:	Dural South No. 1
Operating Co. :	Shell Development (Australia) Pty. Ltd.
Location :	Lat. 33°42' 37", Long. 151° 01' 02" E. 1:250,000 Sydney Sheet No. SI 56/5. Central Sydney Basin, N.S.W.
Elevation :	635' G.L., 649' R.T. Rotary Table used as datum for determining lithological boundary depths in well.
Total Depth :	10035' (drillers depth) 10045' (wire line log depth)
Wire Line Logs :	Laterolog, 517'-6231' Runs 1 - 2. Microlog-Caliper, 517'-10046', Runs 1 - 5. Sonic Log-Caliper, 517'-10038' Runs 1 - 5. Gamma Ray, Surface - 10045' Runs 1 - 6. Neutron Log, 3027'-6236'; 9060'-10045' Continuous Dipmeter, 3027'-10031' Run 1.
Drill Stem Tests :	D.S.T. Nos 1 - 9 were carried out within the interval 4774'-10035'. Only four of the tests were successfully completed.
D.S.T. No. 4	9478' - 9566', Rec. 100' slightly gas cut mud.
" No. 5	9478' - 9566', Rec. 280' very slightly gas cut mud.
D.S.T. No. 7	8854' - 8930', Rec. 100' mud
" No. 9	4774' - 4800', Rec. 100' slightly gas cut mud.

Hydrocarbon shows:

Only gas shows have been recorded in this well; they occurred chiefly over the interval 5100' - 5550' in the Permian Coal Measures sequence.

Material available for study:

Cuttings samples taken every 10' over the interval 40'-10030', together with slabbed cores Nos. 1-9 and some sidewall core samples, were examined. All Wire Line Logs were used.

Major reference used in study:

Dural South No. 1, New South Wales, Well Completion Report - by Shell Development (Australia) Pty. Ltd., 1967.

Earlier studies on well:

Besides routine well-site investigations, Shell undertook thin section studies of cores and also carried out coal rank reflectivity measurements of vitrinite particles on coal and in fine-grained sediments. P.R. Evans of B.M.R. carried out a palynological study of selected core samples below 3000'. Shell made microfaunal analysis of cores, sidewall cores and selected cuttings samples.

GEOLOGY

Introduction

This petrological study was undertaken as part of the B.M.R. review of the Sydney Basin. A microscopic study was carried out on all the samples; in addition, thin section studies were made of selected samples.

Lithological units have been erected in this well using various criteria. Small units have been established where distinctive lithologies occur; where possible these small units have been grouped together on the basis of lithogenetic affinities. Letter-number symbols were used to designate the units; the letter represents the first letter of the well name, and the number identifies the particular rock unit. Numbering commences from the top of the well. Discussion of these units will also start from the top of the well.

UNIT D1. Surface to 120'. Thickness: 120'

General Description.

Black shale predominates with subordinate thin beds of silty mudstone. Sideritic aggregates are common; finely dispersed carbonaceous matter occurs in the shale.

Unit characteristics and boundary criteria.

Unit D1 is characterized by clay and silt which give a curve on the gamma-ray log showing only minor variations with counts remaining at 45-50 A.P.I. units. The low counts recorded over this clayey interval may be due to the influence of either carbonaceous matter present or to a possible low K^{40} content in the clay. The shale is composed of unresolvable clay with dispersed carbonaceous matter, and rare quartz grains (2%). The mudstone comprises quartz (60%) and illitic clay (40%). Diagenetic siderite occurs in disseminated from and as clusters.

Environment of Deposition and provenance.

The occurrence of silty laminations in the shales suggests quiet water deposition. The abundance of carbonaceous matter and diagenetic siderite indicates that reducing conditions existed during and after sedimentation.

UNIT D2. 120' - 790'. Thickness: 670'

General description.

The unit consists predominantly of moderately sorted, fine and medium-grained protoquartzite, with subordinate medium-grained orthoquartzite and thin beds of silty mudstone. Pebbly beds occur in the orthoquartzite.

Unit characteristics and boundary criteria.

The sequence in D2 gives a gamma-ray log which has a fairly regular pattern of peaks and lows, with counts ranging from 30 to 60 A.P.I. units. A similar pattern is given by the resistivity curve below 500 feet, with resistivities ranging from 50-95 ohms m^2/m; the S.P. curve is more variable, and shows some strong negative deflections (-10 to -20 millivolts) characteristic of clean sands.

The sandstone in D2 is quartz-rich (75%-90%), and contains silicified claystone fragments, minor chert and rare volcanic rock fragments; feldspar is absent. At 320' porphyritic andesite pebbles occur in a pebble bed. Flaky graphite is present in the sandstone. Silica cement, which is common throughout, predominates in the fine to medium-grained sandstone; diagenetic siderite cement is important in the medium and coarse-grained sandstone which occurs in the lower half of the unit.

Porosity, which is intergranular, is poor on average (6-12%); however, moderate porosity (12-20%) does exist in the lowermost 200' where coarser-grained sandstone is present. Poor effective porosity in the finer-grained sandstone is due to grain interlocking, and pressure solution. In the coarser-grained sandstone, probably good porosity existed originally but has since been reduced through precipitation of siderite cement.

Important criteria used for determining the upper boundary are the change in lithology from D2 medium-grained quartzose sandstone to D1 mudstone; the change on the gamma-ray log from low counts in D2 to moderage counts in D1 is not so apparent.

Environment of deposition and provenance.

These sandy sediments which predominate were deposited in water where high energy conditions existed - to account for the "cleaning-up" of the sandstone. The thin laminated siltstone and mudstone may indicate more quiet water sedimentation, or may just represent bottom-set beds. Oxidizing conditions are indicated by the development of hematitic siltstone at 330'. No fossils were observed in these sediments.

A fresh-water fluviatile environment is envisaged for this sequence. The mineralogical assemblage indicates a quartz-rich sedimentary source where feldspar has been lost during a second cycle of erosion. Evidence of some metamorphic source is suggested by the presence of graphite and stretched polycrystalline quartz. Some volcanic rock influence is suggested by the presence of rare volcanic rock fragments and andesite pebbles.

UNITS D3-5 790' - 1330' Thickness: 540'

General description

Fine-grained, moderately sorted protoquartzite and silty mudstone comprise D3; below this unit, reddish-brown claystone with pellets occurs and has been designated D4; below that again are fine-grained protoquartzite, silty mudstone and rare subgreywacke designated D5. In this D3-5 grouping there is an overall increase in the clay-silt content as compared with the overlying D2.

Unit characteristics and boundary criteria.

In D3 the protoquartzite gives a gamma-ray curve that has a dog tooth pattern, with counts ranging from 60 to 105 A.P.I. units. The resistivity curve has an undulatory pattern with resistivities averaging 40-50 ohms and increasing to 80 ohms at the base of D3. The S.P. curve shows a constant positive deflection of +5 to +10 millivolts with a strong negative deflection of -10 millivolts at the base, opposite a clean sandstone.

The sandstone in D3 is quartz-rich (70-90%), devoid of feldspar, and contains silicified claystone fragments and brown limonite pellets. Silica is the dominant cement with siderite and minor calcite also present; patches of hematite occur near the base. Intergranular porosity is poor, due to interlocking of grains, pressure solution and quartz overgrowth. The mudstone is illitic and contains finely-crystalline diagenetic siderite. The sand/shale ratio for D3 is 2.2.

The upper boundary of D3 is based on the change from D3 mudstone and fine-grained sandstone to D2 medium-grained sandstones, the change from high gamma-ray counts in D3 to low counts in D2, and the change in S.P. curve from positive deflection in D3 to negative deflection in D2.

In D4, claystone predominates; however the gamma-ray curve, which has a dog-tooth pattern, records anomalous low counts (45-60 A.P.I. units) with one peak of 90 A.P.I. units. The low counts may be due to a deficiency of K^{40} in the clay. The peak at 1070' may be related to the presence of finely dispersed urano-phosphate which is not detectable in thin section: a phosphate test on claystone from 1070' yielded a low precipitate. The resistivity curve shows a low resistivity (10 to 15 ohms), with one peak present opposite a sand layer. The S.P. curve remains constant and has a positive shift (+15 to +20 millivolts).

The claystone in D4 consists of montmorillonitic-type clay (65-90%) with finely dispersed hematite, rare quartz (1%), and dark clay pellets. Authigenic calcite (10-25%) and rare glauconite pellets occur.

The criteria for determining the upper boundary are the change in lithology from D4 claystone to D3 fine-grained sandstone, the change from low gamma-ray counts in D4 to high counts in D3, and the change from low resistivity in D4 to high resistivity in D3.

In D5 the sandstone and mudstone give a gamma-ray curve that has a dog-tooth pattern, with counts of 75 to 105 A.P.I. units. The resistivity pattern shows high values with peaks (60-80 ohms) in the upper half of D5, decreasing to moderate variable resistivity (25-45 ohms) in the lower half. The S.P. curve remains constant, with a progressive negative shift from +15 to +8 millivolts basewards.

Quartz-rich sandstone occurs in D5 together with mudstone containing dispersed carbonaceous matter. The sand/shale ratio is 1.2. At 1145' a fine-grained subgreywacke is present which contains quartz (20%), andesine (5%), rock fragments (50%) - including some of volcanic origin. Intergranular porosity in the sandstone is poor.

Criteria used for determining the upper boundary of D5 are the change of lithology from D5 fine-grained sandstone to D4 claystone, the change on the gamma-ray log from high counts in D5 to low counts in D4, and the change on the resistivity log from high resistivity in D5 to low resistivity in D4.

Environment of deposition and provenance.

Deposition of these sediments is thought to have taken place in a predominantly fresh-water fluviatile environment where both agitated and quiet water conditions occurred. However, shallow water marine conditions accompanied by oxidizing conditions are thought to have existed during deposition of the red claystone layer where rare occurrences of glauconite were recorded. No fossils were observed in this sequence. The mineral assemblage suggests a quartz-rich and clay-rich sedimentary source and a metamorphic source, with some volcanic influence below D4.

UNIT D6-7 1330' - 2730'. Thickness: 1400'

General description.

D6 consists of fine-grained subgreywacke and protoquartzite with pebble beds, alternating with thin beds of siltstone and mudstone; this cyclic sequence is recognizable on the resistivity and gamma-ray logs. In D7 sandy siltstone predominates with minor subgreywacke containing pebbles.

Unit characteristics and boundary criteria.

In D6 the interbedded sequence of sandstone and mudstone can be recognised from the regular dog-tooth pattern of the gamma-ray curve (range 45 to 80 A.P.I. units). The electric logs also show regular undulatory patterns, with resistivities ranging from 20 to 35 ohms, and S.P. ranging from 0 to +25 millivolts.

Characteristics of the sandstone in D6 are: a progressive decrease in quartz from about 60% to about 25% towards the base; the presence of andesine (2-5%) and subordinate oligoclase, albite and K-feldspar; and the importance to silicified claystone, shale and volcanic lithics which increase from 30% to about 70% towards the base. Scattered glauconite is also present. Calcite and siderite (5-20%) are the main cements. Intergranular porosity is poor (6%) due to grain interlocking, welding of lithic grains, and the presence of carbonate cement. The mudstone and siltstone contain illitic and chloritic clay (50-60%) with finely dispersed siderite. Sand/shale ratio is 3.4.

Criteria for determining the upper boundary are the change from D6 fine-grained sandstone rich in quartz and rock fragments to D5 mudstone, and the change from moderate gamma-ray counts in D6 to high counts in D5.

In D7 the sandy siltstone and subgreywacke produce a gamma-ray curve that shows a dog-tooth pattern with greatest variations near the base; counts range between 45 and 75 A.P.I. units. The resistivity curve has an undulatory pattern (15-20 ohms) with occasional peaks (25 to 45 ohms). The S.P. curve shows little character (+20 millivolts) with one peak (0 millivolt line) opposite a sandstone bed.

The siltstone and mudstone of D7 contain quartz (20-75%), rock fragments (10-40%), plagioclase (1%), and, more rarely, claystone pellets. Illitic and chloritic clay are present, together with diagenetic siderite. In the sandstone of D7 there is an increase of claystone fragments towards the base from 15% to 30%; other essential constituents are chert (5-20%), and metaquartzite (5-15%); some volcanic rock fragments (1-3%) are present. Intergranular porosity is poor. The sand/shale ratio is 0.2.

Criteria for establishing the upper boundary are the change from D7 siltstone to D6 fine-grained sandstone rich in rock fragments and quartz, the change from low resistivity in D7 to moderate resistivity in D6, and the negative shift from D7 to D6 on the S.P. curve.

Environment of deposition and provenance.

The associated lithologies suggest deposition under intermittent agitated and quiet water conditions. However, in D7 quiet water conditions seem to have prevailed with possibly some marine influence. No fossils have been recorded in these sediments. The detrital components indicate a granitic and volcanic source for D6, with some sedimentary influence; in D7 there is a strong sedimentary influence particularly near the base.

UNIT D8-10 2730'-4035' Thickness: 1305'

General description.

This sequence has been subdivided on the basis of coal seams and associated lithologies. The succession consists of coal seams about 5' thick, fine to coarse-grained subgreywacke, sandy siltstone and rare claystone. The coal seams can be recognised from the sonic log, and the rank of the coal may be seen in Figure I, which shows the results of reflectivity measurements made by Shell.

Unit characteristics and boundary criteria.

In D8 the subgreywacke, siltstone and thin coal seams give a gamma-ray curve with a sharp dog-tooth pattern showing great variation (counts from 45 to 135 A.P.I. units). The resistivity curve shows a serrated pattern with peaks occurring opposite coals; the resistivities range from 15 to 55 ohms. The S.P. curve shows only minor variations (+20 millivolts), and seems unreliable below 3000'. The sonic log was used for determining coal seams; interval transit time values for the coal ranged from 110 to 140 microseconds/ft.

Medium to low-volatile bituminous coal occurs in D8; however one reflectivity reading at 2875' indicated semi-anthracite rank, which Shell considers questionable. The coal/sand + shale ratio is 0.12. Characteristics of the sandstone are: quartz (5-20%); presence of oligoclase and albite (10-15%); importance of lithic fragments (50-75%), consisting of volcanic rock fragments (5-15%) and silicified claystone fragments; occurrence of chalcedony and metaquartzite grains. Important cements are calcite, and siderite with minor chlorite and fibrous zeolite. Intergranular porosity in the sandstone is poor due to welding of lithic grains and the presence of carbonate cement. In the argillaceous sediments carbonaceous matter is abundant (up to 30%). X-ray diffraction shows the important clay type to be illite. The sand/shale ratio is 2.5.

The upper boundary of D8 has been drawn at the top of the uppermost coal seam; the boundary zone is also marked by the change from D8 medium and coarse-grained sandstone rich in lithic fragments to D7 siltstone.

In D9 the siltstone, thin subgreywacke and rare coal seams give a gamma-ray curve of dog-tooth pattern, with high counts at the top and decreasing basewards (from 135 down to 60 A.P.I. units). The resistivity curve has a serrated pattern with low resistivities (10-15 ohms) broken by occasional peaks (32-50 ohms).

In D9 coal seams are rare; the coal/sand + shale ratio is 0.02. In the siltstone, carbonaceous matter is abundant, and illitic clay, siderite and calcite are present; rare silicified illitic claystone also occurs. In the sandstone, carbonate cement is important (10-60%). Intergranular porosity is poor due to squeezing and welding of lithic grains. The sand/shale ratio is 0.32.

Criteria for determining the upper boundary are: change from D9 siltstone to D8 fine-grained sandstone and the change in gamma-ray curve from high counts in D9 to moderate counts in D8.

In D10 sandstone predominates. A dog-tooth pattern is recorded on the gamma-ray curve which shows low counts (35 A.P.I. units) with rare peaks of 90 A.P.I. units. A serrated pattern is shown by the resistivity curve, with low to moderate values (15-45 ohms).

Rare semi-anthracite coal seams occur; the coal/sand + shale ratio is 0.06. The sandstone in D10 is characterised by low quartz content (1-25%), the importance of volcanic rock fragments (10-40%), and the importance of siderite and calcite cement (40-85%). Intergranular porosity is poor due to carbonate cement.

Criteria for establishing the upper boundary are the change from D10 medium-grained sandstone to D9 siltstone, and the change in the gamma-ray curve from low counts in D10 to high counts in D9.

Environment of deposition and provenance.

Deposition is thought to have taken place in an environment where subsidence was slow during sandstone accumulation and static during coal formation. In the carbonaceous siltstone, possible burrow markings occur, suggesting deposition in tidal flat areas. Although no fossils were observed in these sediments this sequence can be compared lithologically with similar sequences of known Permian age. The detrital components indicate both volcanic rock and sedimentary sources, with an increase in volcanic material towards the base.

UNIT D11-12. 4035' - 5035' Thickness: 1000'

General description.

Thickly bedded pyritic sandy siltstone and rare subgreywacke are present in D11. In D12 an alternating sequence of thin siltstone, claystone and subgreywacke occurs, which can be recognized on both the resistivity and gamma-ray logs.. A dolerite intrusion of unknown age is present in D12.

Unit characteristics and boundary criteria.

In D11 the sandy siltstone and minor subgreywacke give a gamma-ray curve that has a serrated pattern, with minor variations. The curve shows moderate counts (60-75 A.P.I. units) increasing to high counts (90-120 A.P.I. units) at the base. The resistivity curve shows an undulatory pattern, mainly with low resistivities (10-20 ohms).

The siltstone of D11 contains abundant lithic fragments (20-60%), including volcanic rock fragments (10%). Illitic and chloritic clays (20-55%) are common, together with disseminated pyrite, and dispersed carbonaceous matter (up to 15%): patches of calcite and siderite occur. Montmorillonitic claystone has also been recorded during this study. Characteristics of the sandstone include: low quartz content (1-15%); high oligoclase content (20-30%), and volcanic rock fragments (13-48%); chloritization of lithic fragments. The important cement is diagenetic chlorite with "chevaux de frise" texture. Rare occurrences of foraminifera were recorded, particularly the arenaceous forms.

Criteria for establishing the upper boundary are the change in lithology from D11 pyrite-rich siltstone to D10 medium-grained carbon-rich, sandstone and the change in gamma-ray curve from moderate counts in D11 to low counts in D10.

In D12 the sequence consists of alternating sandstone and siltstone, interrupted by a dolerite intrusion. The gamma-ray log has a dog-tooth pattern showing great variation; counts range from 30 to 90 A.P.I. units, with two peaks of 127 A.P.I. units close to the dolerite intrusion. The resistivity curve has a dog-tooth pattern showing moderate resistivities (15-30 ohms), but with high resistivity (90 ohms) opposite the dolerite.

Features of the sandstone in D12 are the rarity of quartz (0-1%), the importance of volcanic rock fragments (15-60%), and the presence of diagenetic chlorite cement and chloritized lithic fragments. Intergranular porosity is slight (6%) due to welding of lithic grains and precipitation of chlorite cement. The siltstone and claystone contain disseminated pyrite and dispersed carbonaceous matter. Foraminifera are apparently absent in D12. The sand/shale ratio is 0.9.

Criteria for determining the upper boundary are the change from D12 fine-grained sandstone and siltstone to D11 siltstone, the change in gamma-ray curve from low counts in D12 to high counts in D11 and the change from moderate resistivity in D12 to low resistivity in D11.

Environment of deposition and provenance.

Deposition of the pyritic, carbonaceous siltstone is thought to have taken place in quiet waters, where reducing conditions developed as a result of restricted water circulation; agitated water conditions probably existed during sandstone deposition in D12. Evidence for marine influence is the presence of arenaceous foraminifera in D11, and the presence of (?) burrow markings could indicate shallow water conditions. Thus a shallow marine environment with restricted water circulation is envisaged for this sequence. The mineral assemblage indicates a predominantly intermediate to basic volcanic rock source.

UNIT D13-14. 5035' - 5620' Thickness: 585'

General description.

Subdivision of this sequence has been based on the presence of coal and associated lithologies. D13 consists of coal seams 5' thick - recognizable on the sonic log - alternating with siltstone and fine-grained subgreywacke. Fine to medium-grained subgreywacke with siltstone interbeds predominates in D14.

Unit characteristics and boundary criteria.

In D13 the siltstone, subgreywacke and thin coal seams give a gamma-ray curve which has a dog-tooth pattern showing moderate counts (75 to 105 A.P.I. units); however strong inflections occur opposite sandstone and coal where low counts (45 A.P.I. units) are recorded. The resistivity curve shows a serrated pattern with minor variations - resistivities vary from 10 to 20 ohms, with rare peaks of 30 and 40 ohms opposite coal seams. Coal seams were located on Plate 1C by using the sonic log; interval transit time values for the coal ranged from 115 to 140 microseconds/ft.

Semi-anthracite coal seams occur in D13; the coal/sand + shale ratio is 0.2. The argillaceous sediments contain chloritic clay with dispersed carbonaceous matter and pyrite. Features of the sandstone are the absence of quartz, the importance of chloritized volcanic rock fragments (35%) and the presence of diagenetic calcite and chlorite. Intergranular porosity is slight due to chlorite and calcite cement filling voids. The sand/shale ratio is 0.42.

The upper boundary of D13 has been drawn at the top of the uppermost coal seam/lens. The other feature used is the change from predominantly siltstone in D13 to fine-grained sandstone and siltstone in D12.

In D14 the subgreywacke and thinly-bedded siltstone gives a gamma-ray curve that shows a serrated pattern with large variations; the moderate to high counts (60-120 A.P.I. units) in this predominantly sandstone sequence appear to be due to the presence of thin siltstone interbeds. The resistivity curve has a dog-tooth pattern but shows moderate values with small variations (25 to 40 ohms).

Characteristics of the sandstone are the absence of quartz, the importance of volcanic fragments (15-20%), and the presence of diagenetic chlorite and calcite cement (20-70%). Intergranular porosity is slight due to welding of lithic grains and diagenetic chlorite and calcite filling pores; permeability is nil. The siltstone contains chloritic and illitic clay with dispersed carbonaceous matter and disseminated pyrite. The sand/shale ratio is 2.5.

Criteria for determining the upper boundary are the change from D14 fine to medium-grained sandstone to D13 siltstone and coal, and the change from moderate resistivity in D14 to low resistivity in D13.

Environment of deposition and provenance.

Sedimentation is thought to have taken place in a shallow deltaic environment where subsidence was slow during sandstone deposition and static during coal formation. Shallow water deposition is suggested by the occurrence of scour-and-fill structures and burrows. Laminations and small scale cross-bedding are present; dipmeter variations also suggest the presence of cross-bedding. No fossils have been recorded. The detrital components indicate a predominantly volcanic rock provenance.

UNIT D15-18. 5620' - 7720' Thickness: 2100'

General description.

This sequence comprises sandy siltstone with minor sandstone. D15 consists of sandy siltstone with minor fine-grained subgreywacke. Massive sandy, pyritic siltstone with claystone interbeds and rare quartz greywacke are present in D16. Massive medium-grained protoquartzite containing pebbles comprises D17. Sandy siltstone with quartz greywacke at the base occurs in D18.

Unit characteristics and boundary criteria.

In D15, the sandy siltstone with minor subgreywacke gives a gamma-ray curve that has a serrated pattern with inflections opposite the sandstone beds; moderate to high counts (75 to 105 A.P.I. units) are recorded. The resistivity curve has a dog-tooth pattern with low to moderate values (10-25 ohms).

In the argillaceous sediments of D15, chloritic clay with dispersed carbonaceous matter is common. Features of the sandstone are the importance of quartz (40%), and the scarcity of volcanic rock fragments (2%). Intergranular porosity is slight due to interlocking and welding of grains. The sand/shale ratio is 0.6.

Criteria for determining the upper boundary are the change from predominantly siltstone in D15 to fine and medium-grained sandstone in D14; the change from D15 sandstone containing quartz to D14 sandstone devoid of quartz; and the presence of arenaceous foraminifera in D15.

In D16 siltstone predominates, and the gamma-ray curve has a serrated pattern with high counts (90-135 A.P.I. units) decreasing to moderate counts (75-90 A.P.I. units) in the lower half of the sequence. The resistivity curve shows a serrated pattern with low to moderate resistivities (20-25 ohms) but with a peak of 40 ohms over one interval.

In D16 the important features of the siltstone are the abundance of quartz (40-70%), widespread dispersed pyrite (2-5%) and carbonaceous matter (5-10%); and the importance of illitic clay (10-60%) with minor chloritic clay. Claystone interbeds contain illitic clay (70-100%) and often montmorillonitic clay.

Criteria for establishing the upper boundary are the change from massive siltstone in D16 to siltstone and sandstone in D15, and the change in gamma-ray curve from high counts in D16 to moderate counts in D15.

In D17 protoquartzite with pebbles predominates, and the gamma-ray curve has a dog-tooth pattern with low counts (52 A.P.I. units); rare moderate to high counts (75-105 A.P.I. units) occur opposite siltstone interbeds. The resistivity curve shows a dog-tooth pattern with moderate resistivities (50-60 ohms).

The sandstone in D17 is characterised by: poor sorting; the importance of quartz (60%), and low grade metamorphic fragments (10%); and the presence of calcite, siderite and silica cement (15%). Intergranular porosity is slight due to interlocking and welding of quartz.

The sand/shale ratio is 3.8. Criteria for determining the upper boundary are the change in lithology from medium-grained protoquartzite in D17 to sandy siltstone in D16, the change in gamma-ray curve from low counts in D17 to moderate counts in D16, and the change from moderate resistivity in D17 to low resistivity in D16.

In D18 massive siltstone predominated with quartz greywacke at the base. The gamma-ray curve has a serrated pattern with moderate to high counts (90-105 A.P.I. units) and rare peaks of 150 A.P.I. units. The resistivity curve shows a dog-tooth pattern of moderate resistivity with the greatest positive inflections opposite claystone beds; average resistivities range from 30 to 40 ohms with occasional peaks of 60 ohms. Resistivity values suggest that sand-size components are important in the siltstone.

Important features of the siltstone in D18 are the high quartz content (50-65%), presence of albite and K-feldspar (2-10%), and the importance of illitic clay together with fine silica (20-45%), and finely disseminated pyrite (1-3%). Characteristics of the sandstone are the poor sorting, abundant quartz (60%), and illitic clay matrix.

The sand/shale ratio is 0.1. Criteria for establishing the upper boundary are the change from D18 sandy siltstone rich in illite to D17 medium-grained sandstone, and the change in gamma-ray curve from moderate to high counts in D18 to low counts in D17.

Environment of deposition and provenance.

Deposition of this predominantly siltstone sequence is thought to have taken place in a quiet shallow marine environment; indications are that reducing conditions, accompanied by restricted water circulation, existed during the accumulation of carbonaceous matter and the formation of pyrite. Clay laminations, burrows and small scale cross-bedding occur in the siltstone.

In the siltstone sequence arenaceous foraminifera have been recorded, with Hyperammina spp. being the predominant arenaceous form. According to Shell (1967) the occurrence of Hyperammina spp. would indicate in certain respects a restricted marine environment. Crespin (1958) supports this view in her discussion of Permian sediments of the Carnarvon Basin, where she states that the deposition of more than 2000 feet of carbonaceous sediments containing occasional Hyperammina tests took place in an area almost completely barred from clear waters of the open sea. The protoquartzite of D17 suggests deposition in agitated water, whilst the poorly sorted quartz greywacke at the base of D18 would indicate more rapid deposition under low energy conditions. These sandstone intervals are barren of microfauna, but solitary corals and rare brachiopods have been recorded from D18. Detrital components indicate a granitic source with some metamorphic and minor volcanic rock influence.

UNIT D19-21. 7720' - 9045' Thickness: 1325'

General description.

This is a predominantly sandstone sequence with medium-grained protoquartzite and subarkose occurring in D19; siltstone with interbedded sandstone occurs in D20; and subarkose is present in D21.

Unit characteristics and boundary criteria.

In D19 protoquartzite and subarkose predominate, and the gamma-ray curve has a serrated pattern with moderate counts (45-75 A.P.I. units) and rare peaks (105 to 135 A.P.I. units) opposite siltstone interbeds. The resistivity curve has a dog-tooth pattern with high resistivities (40 to 100 ohms) and inflections (25-30 ohms) opposite siltstone interbeds.

In the sandstone of D19 important features are the abundant quartz (65-85%); the presence of albite and K-feldspar (totalling 5-10%) and metamorphic rock fragments (3-15%); and the strongly interlocking nature of the grains. Illitic clay matrix and calcite cement occur in the protoquartzite, while silica cement predominates in the subarkose. Intergranular porosity is slight (2-5%) due to interlocking and welding of quartz grains, and the presence of clay matrix and silica cement; permeability is nil. The sand/shale ratio is 8.5.

Criteria for establishing the upper boundary are the change from medium-grained quartz-rich sandstone in D19 to clay-rich siltstone in D18; the change in gamma-ray curve from moderate counts in D19 to high counts in D18; and the change from high resistivity in D19 to moderate resistivity in D18.

In D20 the siltstone with interbedded sandstone gives a gamma-ray curve that has a serrated pattern with high counts (105-150 A.P.I. units), and inflections (75 A.P.I. units) opposite sandstone interbeds. The resistivity curve shows a dog-tooth pattern with low to moderate values (20-25 ohms) and rare peaks (35-55 ohms).

The siltstone in D20 contains chloritic and illitic clay with disseminated pyrite; dispersed carbonaceous matter (up to 10%) is present in the clay. The sandstone present is characterised by quartz (80%) and silica cement (10%). Intergranular porosity is slight. The sand/shale ratio is 0.33.

Criteria for determining the upper boundary are the change from predominantly siltstone in D20 to medium-grained sandstone in D19 and the change from low and moderate resistivity in D20 to high resistivity in D19.

In D21 the sandstone sequence gives a gamma-ray curve showing a serrated pattern with moderate counts (45-90 A.P.I. units); rare peaks (120 A.P.I. units) occur opposite siltstone interbeds. The resistivity curve has a dog-tooth pattern with variable high resistivities (50-100 ohms).

Important features of the sandstone in D21 are the poor sorting, the high quartz content (80%) and significant K-feldspar (5%); the cement is silica (5%). Intergranular porosity is slight (5%) due to the silica cement.

The sand/shale ratio is 12.0. Criteria for establishing the upper boundary are the change from D21 medium-grained sandstone to D20 siltstone; the change in gamma-ray curve from moderate counts in D21 to high counts in D20; and the change from high resistivity in D21 to moderate resistivity in D20.

Environment of deposition and provenance.

Sedimentation is thought to have taken place in shallow water. Agitated conditions, accompanied by rapid deposition, prevailed during sandstone accumulation; more quiet water conditions occurred during siltstone deposition. Minor clay laminations and some churned bedding are present in the sandstone. Arenaceous foraminifera have been recorded, with Hyperammina spp. being abundant in the siltstone of D20; fragments of thick-shelled brachiopods have also been recorded from these sediments.

A shallow marine near-shore environment is envisaged for this sequence. The detrital components suggest a granitic source with minor metamorphic influence.

UNIT D22-24. 9045' - 9990' Thickness: 945'

General description.

This is a predominantly argillaceous sequence with a middle sandstone section. D22 consists of bryozoal mudstone and siltstone, underlain by the sandy limestone and medium-grained protoquartzite of D23; siltstone and mudstone predominate in D24.

Unit characteristics and boundary criteria.

In D22 the mudstone sequence gives a gamma-ray curve with a serrated pattern of high counts (90-120 A.P.I. units). The resistivity curve is undulatory with only minor variations and low to moderate resistivities (15 to 25 ohms). Characteristics of the mudstone are the abundance of bryozoa (25%), and illitic clay (60%), containing disseminated pyrite and dispersed calcite. The siltstone consists mainly of quartz (60%) and some illitic clay.

Criteria for establishing the upper boundary are the change from D22 mudstone to D21 medium-grained sandstone; the presence of bryozoa in D22; the change from low resistivity in D22 to high resistivity in D21, and the change in gamma-ray curve from high counts in D22 to moderate counts in D21.

In D23 the protoquartzite and sandy limestone give a gamma-ray curve having a serrated pattern with moderate counts (45-90 A.P.I. units). The resistivity curve has a dog-tooth pattern with high values (50 to 85 ohms) occurring opposite well-cemented sandstone beds. A sandy recrystallized bryozoal limestone occurs at the top of the sandstone sequence in D23. Features of the sandstone are a high quartz content (70-80%), presence of albite and K-feldspar (2-5%), and granitic fragments; there is strong interlocking of grains. Intergranular porosity is slight (4%) due to grain interlocking, pressure solution, and silica and calcite cement; permeability is nil. The sand/shale ratio is 7.6.

Criteria for determining the upper boundary are the change of lithology from medium-grained sandstone in D23 to illitic mudstone in D22; the sharp change from high resistivity in D23 to low resistivity in D22; and the change in the gamma-ray curve from moderate counts in D23 to high counts in D22.

In D24 mudstone and siltstone predominate. The gamma-ray curve shows a serrated pattern with high counts (75-135 A.P.I. units). The resistivity curve has a dog-tooth pattern with low to moderate resistivities (15-30 ohms); rare peaks (45 and 80 ohms) occur opposite sandstone beds. Features of the mudstone are the presence of quartz (30%), sericite flakes (2%), and illitic clay (65%).

Criteria for establishing the upper boundary are the change from D24 illitic mudstone to D23 medium-grained sandstone; the change from low and moderate resistivity in D24 to high resistivity in D23; and the change in gamma-ray curve from high counts in D24 to moderate counts in D23.

Environment of deposition and provenance.

Deposition of the mudstone took place in quiet waters, whereas the protoquartzite formed in shallow waters where the pH conditions were suitable for carbonated cement to be formed. A near-shore environment is envisaged due to the occurrence of churned bedding caused by burrowing organisms in the sandstone. Fauna present includes abundant arenaceous foraminifera (in D22), abundant bryozoa (in D22 and D23), and lagenids (in D22). The presence of bryozoa and lagenids suggests moderately shallow warm waters where adequate circulation existed.

Evidence suggests that the sediments of D22-24 were deposited in a shallow marine environment where open sea conditions existed. The detrital components suggest a granitic source with minor metamorphic influence.

UNIT D25. 9990' - 10035' T.D. Thickness: 45' +

General description.

This sequence consists of a weathered tuff with reddish-brown siderite crystals. The tuff is regarded by Shell as economic basement - but it should be remembered that only 45' of tuff were penetrated before drilling terminated.

Unit characteristics and boundary criteria.

In D25 the tuff gives a gamma-ray curve with a serrated pattern and high counts (75-105 A.P.I. units). The resistivity curve shows low to moderate values (5-35 ohms). Features of the tuff are the abundance of dark brown idiomorphic siderite crystals (15-20%), occurrence of thin bands of spheroids and shards of devitrified glass, and abundance of montmorillonitic-type clay.

Criteria for establishing the upper boundary are: the marked lithological change from D25 weathered tuff to predominantly mudstone in D24, and the change from montmorillonitic-type clay in D25 to illitic clay in D24.

Environment of deposition and provenance.

The banded nature and the absence of non-volcanic clasts of the tuff suggest that deposition took place in water outside the sphere of terrigenous influence. Devitrification accompanied by formation of montmorillonitic clay occurred after deposition. Indications are that this pyroclastic deposit was derived from an erupting volcano of acid to intermediate composition.

There is no evidence to indicate the age of this unit, nor is there any indication of a disconformity at the top. Also there are no signs of a dip change nor any variation in the degree of diagenesis between the tuff and the overlying sediments. Therefore it is possible that D25 represents a tuffaceous horizon within the Permian succession - as is found within Unit S10 described by Alcock (1968) from Stockyard Mountain (Farmout) No. 1 Well, further to the south.

CONCLUSIONS

In Dural South No. 1 twenty five litholgical units have been recognised and informal nomenclature has been used to identify them.

From a study of grain size, mineralogical composition, wire-line logs and fossiloccurrences, it has been possible to group together genetically related units whose sediments exhibit features which are characteristic of a particular type of environment and provenance. The broad lithostratigraphy determined in this study is similar to that recognized by Shell Development (Australia) (1962); there is general agreement in the broad unit boundaries recognised by that company and the B.M.R. (see Table I).

A summary of the major units is plotted on Figure 2. Sediments of D1-7 were deposited under fresh-water fluviatile conditions gradually changing from shallow marine conditions near the base. The provenance was predominantly sedimentary with some granitic, metamorphic and minor volcanic rock influence. This sequence broadly corresponds to the accepted Triassic section.

Sedimentation of D8-14 took place under more deltaic conditions, accompanied by coal development, from a predominantly volcanic rock source; the base is rather lower than the Company's pick of the base of the Upper Coal Measures. Sediments of D15-24 were deposited under more marine conditions, and mainly derived from a granitic source. The well bottomed in altered tuff of D25, regarded by Shell as economic basement; it is thought possible, however, that the tuff may represent an horizon within the Permian succession.

It was noted that only minor amounts of kaolinite occurred in sediments of the coal sequences, suggesting either a scarcity of detrital kaolinite or transformation of kaolinite to illite during diagenesis. Although most of the volcanic material present appears to have been derived from a volcanic land surface, the presence of thin claystones containing montmorillonitic clay suggests phases of contemporaneous vulcanism during sedimentation.

Reflectance studies of dark marine siltstone indicate that the organic matter present is of humic origin with a high percentage of fixed carbon. Evidence of carbonization has also been observed by Evans (1967) during his study of the spores. Such sediments cannot be considered as suitable source rocks in their present state, if the carbon ratio theory (Levorsen 1967) is accepted. However, the presence of carbonaceous matter could mean that oil and gas were originally present; it may be that the hydrocarbons migrated during the process of diagenesis.

Only the sandstone of D2 exhibits suitable reservoir characteristics, but it lacks an adequate caprock.

In conclusion, the results suggest that in the sediments penetrated by Dural South No. 1 conditions would have been unfavourable for both the generation and local accumulation of hydrocarbons.

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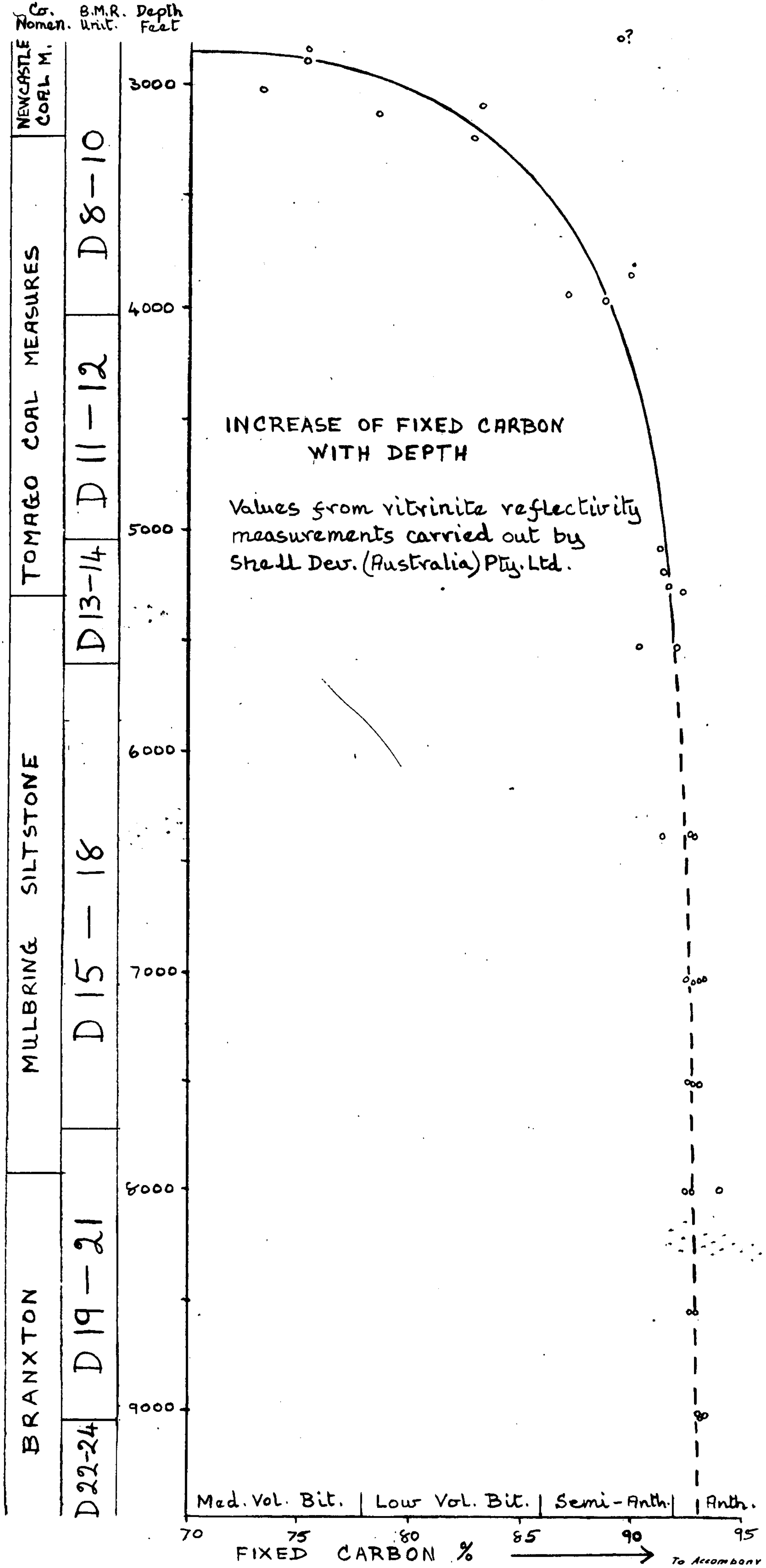
DURAL SOUTH (SHELL) No1

Figure 1

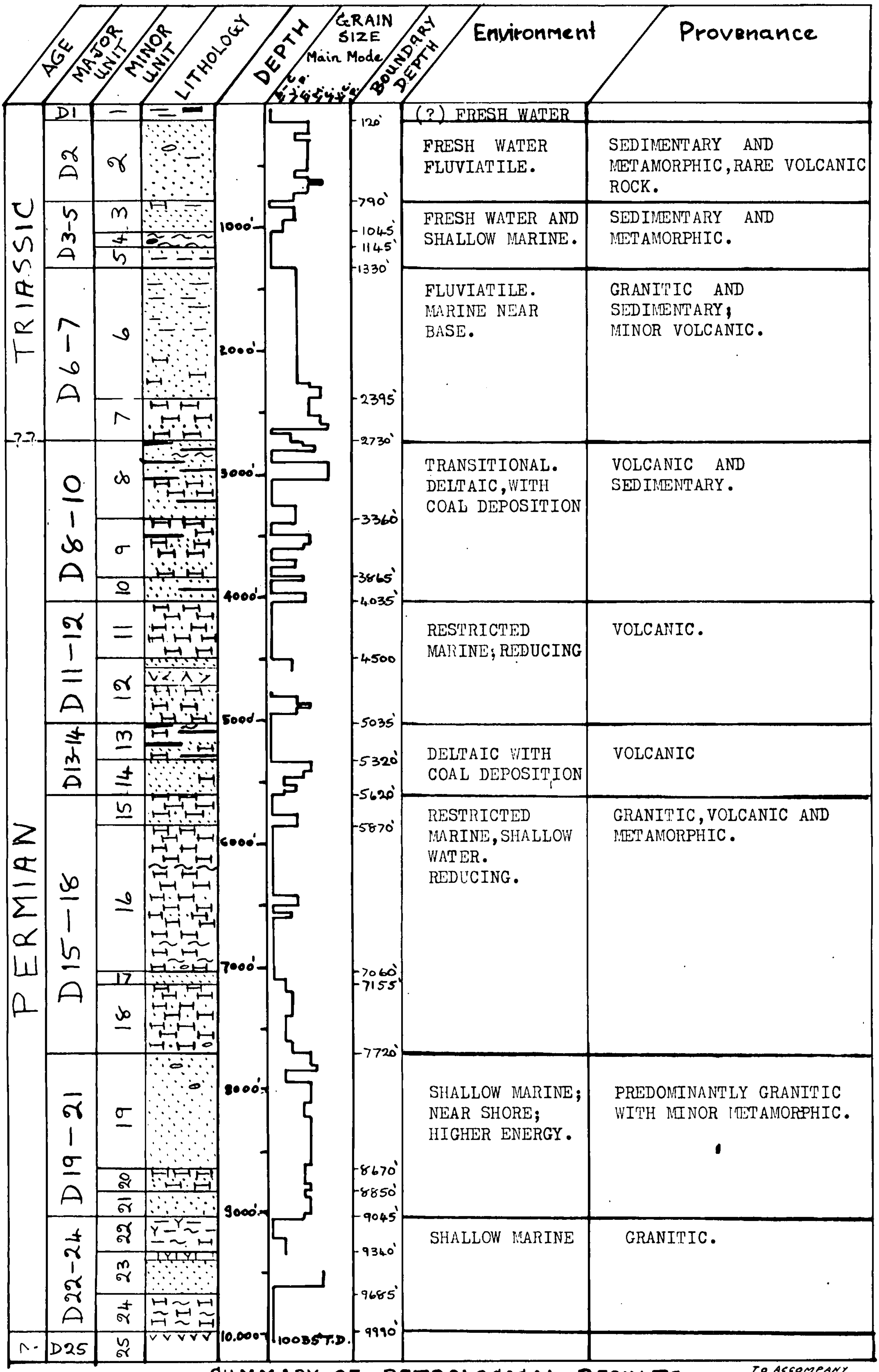


INCREASE OF FIXED CARBON WITH DEPTH

Values from vitrinite reflectivity measurements carried out by Shell Dev. (Australia) Pty. Ltd.

To Accompany Record 1967/160

DURAL SOUTH (SHELL) No.1



AGE	MAJOR UNIT	MINOR UNIT	BOUNDARY DEPTH	Environment	Provenance
TRIASSIC	D1	1	120'	(?) FRESH WATER	
	D2	2	790'	FRESH WATER FLUVIATILE.	SEDIMENTARY AND METAMORPHIC, RARE VOLCANIC ROCK.
	D3-5	3	1045'	FRESH WATER AND SHALLOW MARINE.	SEDIMENTARY AND METAMORPHIC.
		4	1145'		
		5	1330'		
	D6-7	6	2395'	FLUVIATILE. MARINE NEAR BASE.	GRANITIC AND SEDIMENTARY; MINOR VOLCANIC.
		7	2730'		
??					
PERMIAN	D8-10	8	3360'	TRANSITIONAL. DELTAIC, WITH COAL DEPOSITION	VOLCANIC AND SEDIMENTARY.
		9	3865'		
		10	4035'		
	D11-12	11	4500	RESTRICTED MARINE; REDUCING	VOLCANIC.
		12	5035'		
	D13-14	13	5320'	DELTAIC WITH COAL DEPOSITION	VOLCANIC
		14	5620'		
	D15-18	15	5870'	RESTRICTED MARINE, SHALLOW WATER. REDUCING.	GRANITIC, VOLCANIC AND METAMORPHIC.
		16	7060'		
		17	7155'		
		18	7720'		
	D19-21	19	8670'	SHALLOW MARINE; NEAR SHORE; HIGHER ENERGY.	PREDOMINANTLY GRANITIC WITH MINOR METAMORPHIC.
		20	8850'		
		21	9045'		
	D22-24	22	9340'	SHALLOW MARINE	GRANITIC.
		23	9685'		
		24	9990'		
?.	D25	25			

SUMMARY OF PETROLOGICAL RESULTS

To ACCOMPANY RECORD No 1967/160

TABLE I

Comparison of B.M.R. Informal Units with divisions used by Shell Development in Dural South No. 1 Well.

B.M.R. INFORMAL UNIT		DEPTHS (Feet)		COMPANY NOMENCLATURE	
MINOR	MAJOR			FORMATION SUBGROUP	GROUP
D1		120	120	Ashfield Shale	WIANAMATTA
D2		790		Hawkesbury Ss.	
			900		
D3	D3 - 5	1045		Gosford	NARRABEEN
D4		1145			
D5		1330			
			2034		
D6	D6 - 7	2395		Clifton Subgroup	
D7		2730	2730		
			3233	Newcastle C.M.	UPPER COAL MEASURES
D8	D8 - 10	3360		Tomago Coal Measures	
D9		3865			
D10		4035			
D11	D11 - 12	4500			
D12		5035			
			5296		
D13	D13 - 14	5320		Mulbring Siltstone	MAITLAND
D14		5620			
D15	D15 - 18	5870			
D16		7060			
D17		7155			
D18		7720			
			7923		
D19	D19 - 21	8670		Branxton	
D20		8850			
D21		9045			
D22	D22 - 24	9340			
D23		9685			
D24		9990			
			10005		
D25		10035 T.D.	10035	Econ. Basement	

WELL NAME, No. Dural South No. 1
OPERATING Co. Shell Development (Aust) Pty. Ltd.
WELL LOCATION
Lat. 33° 42' 37" S. - Long. 151° 01' 02" E.
Basin : SYDNEY.
State : N.S.W.

Tenement No.s : 102 & 103.
1:250,000 Sheet No. SI 56-5

ELEVATION (A.S.L.)
: Ground Level 635 ft
: R.T. Datum 649 ft

SAMPLE STORAGE
: B.M.R., Canberra.
: N.S.W. Mines Dept., Sydney.

HYDROCARBON SYMBOLS
- ◒ Show of oil
- ⊖ Trace of oil
- ☼ Show of gas
- -O- Trace of gas
- ◊ Fluorescence

MISCELLANEOUS
- Interval and Number of Formation Test
- ⋈ No sample available from interval

VERTICAL SCALE: 0, 50, 100, 200 ft.

PETROGRAPHIC WELL LOG
DURAL SOUTH (SHELL) No. 1

Geology by: P. HAWKINS & S. OZIMIC

PLATE 1A

LITHOLOGICAL SYMBOLS
- Sidewall core.
- Metamorphic rock.
- Ab. = Abundant.
- Siderite rock.
- Basic Igneous rock.
- Pyroclastic rock.
- Breccia to conglomerate
- Quartz sand, sandstone
- Siltstone
- Claystone
- Limestone
- Dolomite
- Coal
- Shale and mudstone
- Feldspar
- Calcirudite
- Calcarenite
- Calcilutite

MINERAL ABBREVIATIONS
- Limonite
- Siderite
- Lithics
- Mica
- Oolith
- Pellet
- Sph: Sphene.
- To : Tourmaline
- Zr : Zircon
- Ap : Apatite
- Ca : Calcite
- Ck : Kaolinite.
- Do : Dolomite.
- Fe : Iron Oxide
- He : Haematite.
- Si : Silica
- St : Siderite.
- Chl : Chlorite.
- Gl : Glauconite.
- Gt : Graphite.
- Py : Pyrite.

DESCRIPTIONS OF CUTTINGS

(Description ③ refers to lithological pattern ③ at corresponding depth)

① Shale: black, firm, carbonaceous, micaceous, sideritic. Thin silty laminations.
② Mudstone: Lt. brown, mica flakes, carb. specks, sideritic.
③ Silty mudstone: Dk. brown, firm, clayey, qz, rare feldspar, mica, carb. specks & lenses. Siderite.
④ Qz. Sandstone: Lt. grey, firm, microcryst. siliceous fragments, mica, graphite flakes. Grain interlocking. Silica, rare siderite and kaolinite.

① Mudstone: Dk. grey. (Caving)
② Mudstone: Dk. brown, & reddish brown, silty, limonitic, haematitic.
③ Qz. Sandstone: Lt. grey, metaquartzite, microcryst. siliceous frag., chloritic frag. Pebbles of andesite. Mica flakes. Grain interlocking. Silica, some clay matrix.

① Mudstone: Dk grey, firm. (Caving)
② Mudstone: Dk. brown, sandy, silty, locally sideritic. Carbonaceous flakes.
③ Lith. Qz. Sandstone: Lt. grey, green chloritic fragments, microcryst. siliceous frag., rare metaquartzite, rare limonite pellets. Strong grain interlocking. Silica, minor kaolinite, siderite and calcite

① Well cement
② Mudstone: Dk. brown, ironstained.
③ Lith. Qz. Sandstone: Lt. grey, microcryst. siliceous fragments, chloritic fragments. Siderite cement; minor secondary silica

① Mudstone: Dk. brown, silty, sandy, rare thin sand laminations. Illitic clays with finely cryst. siderite. Carbonaceous matter.
② Lithic Sandstone: Med. grey, rare feldspar, lithics of clean microcryst. siliceous frag., chloritized siliceous frag., chloritic frag., rare brown limonite pellets. Carbonaceous matter. Silica and patches of siderite cement.

① Claystone: Dk. red-brown, rare qz, rare dark clay pellets. Clay with finely dispersed iron oxide. Calcite. Lt. grey claystone with iron oxide specks.
② Mudstone: Brown & purple, firm, sandy, clayey, silty, some ironstaining. Carbonaceous matter.
③ Lithic Sandstone: Lt. brown and grey, lithics of microcryst. siliceous frag., chloritic frag., rare metaquartzite. Ab. lithics at 1140-50'. Silica, calcite, siderite cement. Patches of iron oxide

① Mudstone: Lt. grey-brown, firm, ironstained streaks.
② Lithic Sandstone: Lt. grey, minor feldspar. Lithics of microcryst. siliceous frag., green chloritic siliceous frag., rare metaquartzite, claystone fragments. Calcite, siderite, minor silica cement.
③ Claystone: Lt. green-grey, firm, with brown ironstained patches.

① Mudstone: Lt. brown-grey, firm, silty, sandy and clayey locally. Illitic clay with siderite and calcite patches. Dissem. carbonaceous matter.
② Lithic Sandstone: Lt. grey, minor feldspar. Lithics of microcryst. siliceous frag., chloritic siliceous frag., claystone fragments. Calcite, siderite, minor silica cement.

① Mudstone: Med. grey-brown, silty and clayey, rare sand laminations. Disseminated carbonaceous matter. Red-brown claystone at 1830'.
② Lithic Sandstone: Lt. grey, feldspar, grey microcryst. siliceous frag., chalcedonic frag., green chloritic frag., brown claystone frag., rare metaquartzite. Mica flakes. Calcite with minor siderite and silica cement.

DESCRIPTION OF INTERPRETED LITHOLOGY

Formation ← Test Data — Rock Name (after Pettijohn, 1957)

BLACK SHALE with thin beds of MUDSTONE.

Shale: Black, carbonaceous with thin silty and sandy laminations. Unresolvable clay. Siderite aggregates and clusters (up to 25% of rock), minor calcite.

Silty Mudstone: Light-dark brown, silt-sand size quartz, rare orthoclase, rare chert frag; carb. specks. Illitic clay. Disseminated microcryst siderite. Rare calcite.

PROTOQUARTZITES, subordinate ORTHOQUARTZITES, rare SUBGREYWACKE and thinly interbedded MUDSTONES.

Mudstones: Brown, thinly bedded, silty, with rare thin sand laminations, locally sideritic. Reddish-brown mudstone at 350' with dispersed haematite in illitic clay matrix.

Orthoquartzite: Grey, subangular, medium-grained, PEBBLY at 320'-350', and moderately sorted. Composite & undulose quartz, feldspar absent. Minor chert, metaquartzite, clean microcryst. siliceous fragments, and chloritic siliceous fragments. Pebbles of porphyritic andesite. Strong interlocking of quartz, pressure solution, secondary quartz (5%). Siderite cement in pebbly sandstone; rare kaolinite clay.

Subgreywacke: Grey, angular, fine-grained & mod. sorted. Quartz, feldspar absent. Clean microcryst. siliceous frag., chloritic sil. frag. (30%). Grain welding, siderite cement (10%).

Orthoquartzite: Grey. As for interval 230'-435'.

Protoquartzite: Grey, ang.-subangular, fine-grained & mod. sorted. Composite quartz, feldspar absent. Chloritic siliceous frag., minor clean microcryst. sil. frag. & chloritic fragments. Interlocking of grains. Calcite & minor silica cement.

Protoquartzite: Grey, subangular, medium & coarse-grained, fine-grained below 720', and moderately sorted. Undulose & strained quartz, feldspar absent. Chloritic siliceous frag., rare microcryst. siliceous frag., and chloritic fragments. Interlocking of grains. Diagenetic siderite and minor silica cement.

Interval 120'-230': Protoquartzite similar to above.

PROTOQUARTZITES, rare SUBGREYWACKE, RED CLAYSTONE, subordinate MUDSTONES.

Mudstones: Brown, silty and sandy, rare thin sand laminations. Illitic clay with finely crystalline diagenetic siderite. Dispersed carbonaceous matter.

Protoquartzite: Grey, ang.-subangular, fine-grained, v. fine-grained below 950', and mod. to well sorted. Undulose quartz, qz. with overgrowths, feldspar absent. Clean microcryst. siliceous frag., chloritic siliceous frag., rare limonite pellets. Minor muscovite. Interlocking of grains. Siderite and silica cement, minor calcite & clay, patches of haematite at base.

Claystone: Reddish-brown & greenish grey, rare quartz, rare dark clay PELLETS. Rare ferriferous chlorite fragments. Montmorillonitic clay with finely dispersed haematite. Authig. calcite as crystals and patches. Grey claystone contains iron oxide specks. Purple mudstone at base.

Subgreywacke: Brown, subround.-rounded, fine-grained and poorly sorted. Composite qz, feldspar (andesine)-5%. Ab. clean microcryst. siliceous frag., chloritic fragments. Interlocking of grains. Coarsely recryst. calcite & siderite.

Protoquartzite: Grey-brown. As above.

Mudstone: Brown, silty and sandy. Disseminated carbonaceous matter.

SUBGREYWACKES & PROTOQUARTZITES with alternating thin beds of MUDSTONE & CLAYSTONE.

Claystone: Greenish grey, with light brown ironstained patches.

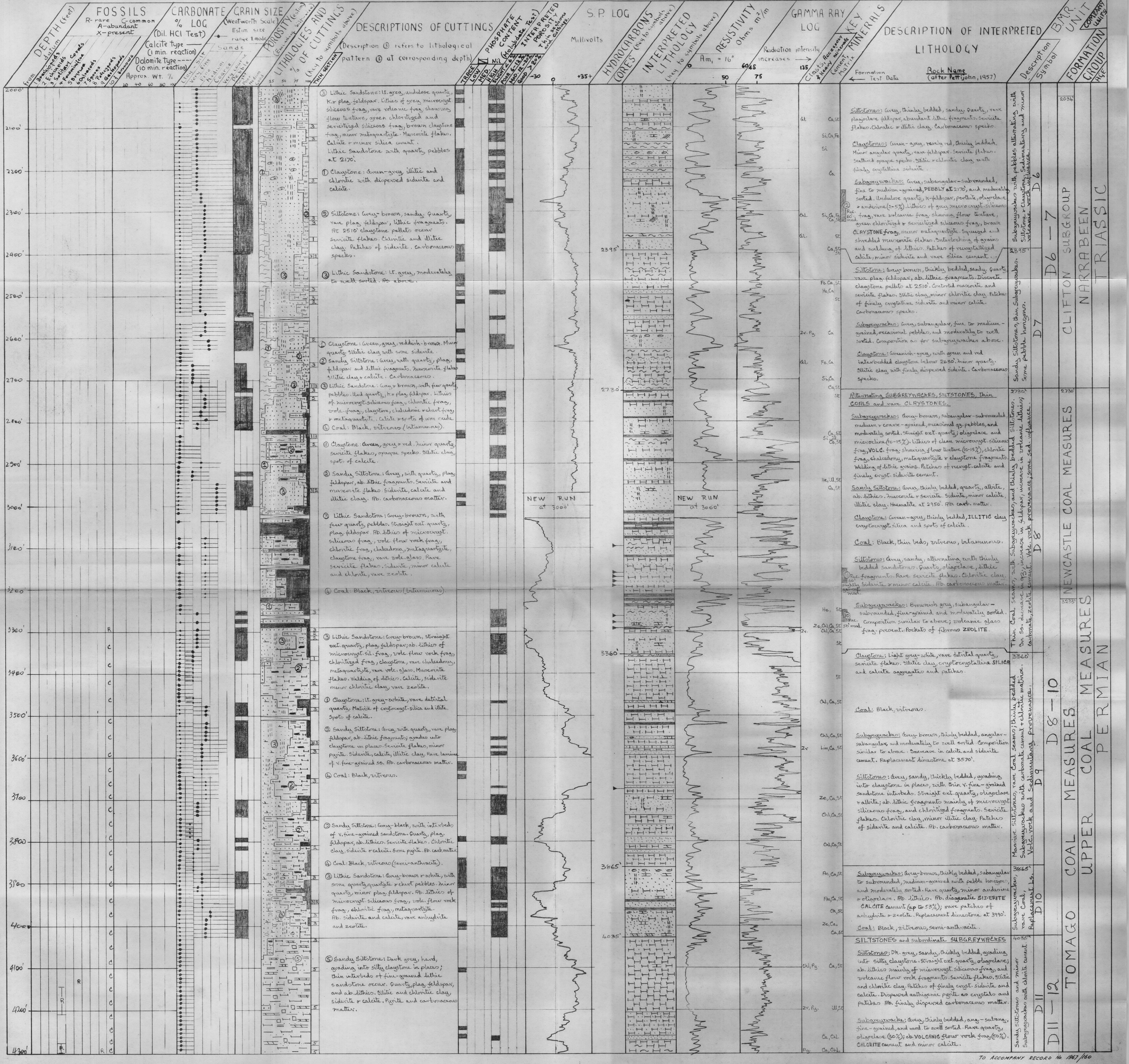
Subgreywackes: Grey, subangular, fine-grained and moderately sorted. Quartz with overgrowths, feldspar - andesine (2-5%). Clean microcryst. siliceous frag., chloritic siliceous frag., green chloritic frag., rare metaquartzite and chalcedonic frag., and brown claystone fragments. Contorted muscovite flakes. Interlocking of grains. Calcite and siderite and minor silica cement. Calcite cement predominates below 1600'.

Mudstones: Brown-grey, silty with silt-size angular quartz grains. Sandy and clayey horizons, rare thin sand laminations. Illitic clay with minor chloritic clay containing finely recrystallized siderite and calcite as crystal aggregates and patches. Finely disseminated carbonaceous matter.

Protoquartzites: Grey, subangular, fine-grained and moderately sorted.

TO ACCOMPANY RECORD No. 1962/160

PLATE 1B



DESCRIPTIONS OF CUTTINGS

(Description ③ refers to lithological pattern ③ at corresponding depth.)

③ Lithic Sandstone: Lt. grey, undulose quartz, K & plag. feldspar. Lithics of grey microcryst. siliceous frag., rare volcanic frag. showing flow texture, green chloritized and sericitized siliceous frag., brown claystone frag., minor metaquartzite. Muscovite flakes. Calcite & minor silica cement. Lithic Sandstone with quartz pebbles at 2170'.

① Claystone: Green-grey, illitic and chloritic with dispersed siderite and calcite.

② Siltstone: Grey-brown, sandy. Quartz, rare plag. feldspar, lithic fragments. At 2510' claystone pellets occur. Sericite flakes. Chloritic and illitic clay. Patches of siderite, carbonaceous specks.

③ Lithic Sandstone: Lt. grey, moderately to well sorted. As above.

① Claystone: Green, grey, reddish-brown. Minor quartz. Illitic clay with some siderite.

② Sandy Siltstone: Grey, with quartz, plag. feldspar and lithic fragments. Muscovite flakes. Illitic clay & calcite. Carbonaceous.

③ Lithic Sandstone: Grey & brown, with few quartz pebbles. Und. quartz, K & plag. feldspar. Lithics of microcryst. siliceous frag., chloritic frag., volc. frag., claystone, chalcedonic & chert frag., & metaquartzite. Calcite & spots of iron oxide.

④ Coal: Black, vitreous (bituminous).

① Claystone: Green, grey & red. Minor quartz, sericite flakes, opaque specks. Illitic clay, spots of calcite.

② Sandy Siltstone: Grey, with quartz, plag. feldspar, ab. lithic fragments. Sericite and muscovite flakes. Siderite, calcite and illitic clay. Ab. carbonaceous matter.

③ Lithic Sandstone: Grey-brown, with few quartz pebbles. Straight ext. quartz, plag. feldspar. Ab. lithics of microcryst. siliceous frag., volc. flow rock frag., chloritic frag., chalcedony, metaquartzite, claystone frag., rare volc. glass. Rare sericite flakes. Siderite, minor calcite and chlorite, rare zeolite.

④ Coal: Black, vitreous (bituminous).

③ Lithic Sandstone: Grey-brown, straight ext. quartz, plag. feldspar; ab. lithics of microcryst. sil. frag., volc. flow rock frag., chloritized frag., claystone, rare chalcedony, metaquartzite, rare volc. glass. Muscovite flakes. Welding of lithics. Calcite, siderite minor chloritic clay, rare zeolite.

① Claystone: Lt. grey-white, rare detrital quartz. Matrix of crytocryst. silica and illite. Spots of calcite.

② Sandy Siltstone: Grey, with quartz, rare plag. feldspar, ab. lithic fragments; grades into claystone in places. Sericite flakes, minor pyrite. Siderite, calcite, illitic clay. Rare laminae of v. fine-grained ss. Ab. carbonaceous matter.

④ Coal: Black, vitreous.

② Sandy Siltstone: Grey-black, with interbeds of v. fine-grained sandstone. Quartz, plag. feldspar, ab. lithics. Sericite flakes. Chloritic clay, siderite & calcite. Some pyrite. Ab. carb. matter.

④ Coal: Black, vitreous (semi-anthracite).

③ Lithic Sandstone: Grey-brown & white, with some quartz, quartzite & chert pebbles. Minor quartz, minor plag. feldspar. Ab. lithics of microcryst. siliceous frag., volc. flow rock frag., chloritic frag., metaquartzite. Ab. siderite and calcite, rare anhydrite and zeolite.

⑤ Sandy Siltstone: Dark grey, hard, grading into silty claystone in places; thin interbeds of fine-grained lithic sandstone occur. Quartz, plag. feldspar, and ab. lithics. Illitic and chloritic clay, siderite & calcite. Pyrite and carbonaceous matter.

DESCRIPTION OF INTERPRETED LITHOLOGY

Formation ← Test Data

Rock Name (after Pettijohn, 1957)

Siltstones: Grey, thinly bedded, sandy. Quartz, rare plagioclase feldspar, abundant lithic fragments. Sericite flakes. Chloritic & illitic clay. Carbonaceous specks.

Claystones: Green-grey, rarely red, thinly bedded. Minor angular quartz, rare feldspar. Sericite flakes. Scattered opaque specks. Illitic & chloritic clay with finely crystalline siderite.

Subgreywackes: Grey, subangular-subrounded, fine to medium-grained, PEBBLY at 2170', and moderately sorted. Undulose quartz, K-feldspar, perthite, oligoclase & andesine (2-5%). Lithics of grey microcryst. siliceous frag., rare volcanic frag. showing flow texture, green chloritized & sericitized siliceous frag., brown CLAYSTONE frag., minor metaquartzite. Squeezed and shredded muscovite flakes. Interlocking of grains and welding of lithics. Patches of recrystallized calcite, minor siderite and rare silica cement.

Siltstone: Grey-brown, thickly bedded, sandy. Quartz rare plag. feldspar, ab. lithic fragments. Discrete claystone pellets at 2510'. Contorted muscovite and sericite flakes. Illitic clay, minor chloritic clay. Patches of finely crystalline siderite and minor calcite. Carbonaceous specks.

Subgreywackes: Grey, subangular, fine to medium-grained, occasional pebbles, and moderately to well sorted. Composition as for subgreywackes above.

Claystone: Greenish-grey, with green and red interbedded claystone below 2630'. Minor quartz. Illitic clay with finely dispersed siderite. Carbonaceous specks.

Alternating SUBGREYWACKES, SILTSTONES, thin COALS and rare CLAYSTONES.

Subgreywackes: Grey-brown, subangular-subrounded, medium & coarse-grained, occasional qz. pebbles, and moderately sorted. Straight ext. quartz; oligoclase and microcline (10-15%). Lithics of clean microcryst. siliceous frag., VOLC. frag. showing flow texture (10-15%), chloritic frag., chalcedony, metaquartzite & claystone fragments. Welding of lithic grains. Patches of recryst. calcite and finely cryst. siderite cement.

Sandy Siltstone: Grey, thinly bedded, quartz, albite, ab. lithics. Muscovite & sericite. Siderite, minor calcite, illitic clay. Haematite at 2950'. Ab. carb. matter.

Claystone: Green-grey, thinly bedded, ILLITIC clay cryptocryst. silica and spots of calcite.

Coal: Black, thin beds, vitreous, bituminous.

Siltstones: Grey, sandy, alternating with thinly bedded sandstones. Quartz, oligoclase, lithic fragments. Rare sericite flakes. Chloritic clay. Siderite & minor calcite. Ab. carbonaceous matter.

Subgreywackes: Brownish grey, subangular-subrounded, fine-grained and moderately sorted. Composition similar to above; volcanic glass frag. present. Pockets of fibrous ZEOLITE.

Claystone: Light grey-white, rare detrital quartz, sericite flakes. Illitic clay, cryptocrystalline SILICA and calcite aggregates and patches.

Coal: Black, vitreous.

Subgreywackes: Grey-brown, thinly bedded, angular-subangular, and moderately to well sorted. Composition similar to above. Increase in calcite and siderite cement. Replacement limestone at 3570'.

Siltstones: Grey, sandy, thickly bedded, grading into claystone in places, with thin v. fine-grained sandstone interbeds. Straight ext. quartz, oligoclase & albite; ab. lithic fragments mainly of microcryst. siliceous frag., and chloritized fragments. Sericite flakes. Chloritic clay, minor illitic clay. Patches of siderite and calcite. Ab. carbonaceous matter.

Subgreywackes: Grey-brown, thickly bedded, subangular to subrounded, medium-grained with pebble horizons, and moderately sorted. Rare quartz, minor andesine & oligoclase. Ab. lithics. Ab. diagenetic SIDERITE CALCITE cement (up to 53%); rare patches of anhydrite & zeolite. Replacement limestone at 3990'.

Coal: Black, vitreous, semi-anthracite.

SILTSTONES and subordinate SUBGREYWACKES

Siltstones: Dk. grey, sandy, thickly bedded, grading into silty claystone. Straight ext. quartz, oligoclase; ab. lithics mainly of microcryst. siliceous frag., and volcanic flow rock fragments. Sericite flakes. Illitic and chloritic clay. Patches of finely cryst. siderite and calcite. Dispersed authigenic pyrite as crystals and patches. Ab. finely dispersed carbonaceous matter.

Subgreywacke: Grey, thinly bedded, ang.-subang., fine-grained, and mod. to well sorted. Rare quartz, oligoclase (30%); ab. VOLCANIC flow rock frag. (50%). CHLORITE cement and minor calcite.

Description

Subgreywackes with pebbles alternating with Siltstone & Claystone. Sedimentary and minor volcanic rock influence.

2395'

Sandy Siltstones, thin Subgreywackes. Some pebble horizons.

2730'

Thin Coal seams, with Subgreywackes, and thinly bedded Siltstones. In ss. decrease in qz.; increase in feldspar, increase in volcanic lithics; carbonate, zeolite cement. Volc. rock provenance; some sed. influence.

3360'

Massive Siltstones, rare Coal seams; thinly bedded Subgreywackes with carbonate cement + chloritic matrix. Volc. rock and Sedimentary provenance.

3865'

Subgreywackes, rare Coal, Replacement L.s.

4035'

Sandy Siltstones and minor Subgreywackes with chlorite cement.

TO ACCOMPANY RECORD No. 1967/160

PLATE 1C

DESCRIPTIONS OF CUTTINGS

(Description ③ refers to lithological pattern ③ at corresponding depth.)

⑤ Siltstone: Grey, sandy, hard, grading into claystone in places; thin interbeds of lithic sandstone occur. Rare quartz, plag. feldspar, lithic fragments. Montmorillonitic and chloritic clay, rare calcite. Pyrite and carbonaceous matter.

③ Lithic Sandstone: Greenish-grey, rare quartz, plag. feldspar; ab. volcanic flow rock fragments. Calcite cement. Pyrite specks.

③ Lith. Sandstone: Green, chloritized lithics. Ab. pyrite.
⑤ Siltstone: Grey, pyritic. Silver grey phyllite below 4550' Contact Zone.

⑥ Dolerite: Grey, green and brown, fine and medium-grained. Plag. feldspar laths and brown augite crystals. Iron oxide crystals.

③ Lith. Sandstone: Greenish-grey.
⑤ Siltstone: Grey; phyllite fragments
Contact Zone

③ Lithic Sandstone: Grey, greenish brown, quartz absent, oligoclase feldspar; ab. lithics of volcanic flow rock frag., brown volc. flow rock frag., chloritized frag., chloritic siltstone fragments. Chlorite and calcite cement. Pyrite.

③ Lith. Qz. Sandstone: Grey, undulose quartz, feldspar absent; ab. metaquartzite and microcryst. siliceous fragments. Interlocking of grains. Calcite, siderite, rare kaolinite.

⑤ Siltstone: Grey & black, sandy, hard, pyritic carbonaceous, grading into silty claystone. Quartz and lithic fragments. Chloritic clay with dispersed carbonaceous matter. Minor calcite.

④ Coal: Black, vitreous, (semi-anthracite).

③ Lithic Sandstone: Green, grey, & brown, quartz absent, oligoclase & albite; ab. lithics of volcanic flow rock frag., brown chloritized volcanic flow rock frag., microcryst. siliceous frag., chloritic fragments. Chloritized mica. Chlorite and calcite cement.

⑤ Siltstone: Grey & brown, sandy, micaceous, carbonaceous, grading into claystone in places. Patches of carbonate. Thinly laminated.

③ Lithic Sandstone: Grey & brown, quartz absent, oligoclase & albite; lithics of volcanic flow rock frag. – some limonite stained, chloritic fragments. Calcite & minor siderite cement. Pyrite specks.

⑤ Siltstone: Grey-black, sandy, grading to shale in places. Quartz, plag. feldspar, lithic fragments. Sericite flakes. Chloritic clay with dispersed carbonaceous matter. Minor calcite. Pyrite.

③ Lithic Sandstone: Grey, silty, with quartz, oligoclase; lithics of microcryst. siliceous frag, rare volc. flow rock frag. Chloritic clay.

⑤ Siltstone: Grey-black, hard, sandy and clayey. Quartz, rare plag., lithic fragments. Muscovite flakes. Illitic and chloritic clay, minor calcite. Dispersed pyrite and carbonaceous matter.

② Claystone: Brown, silty, quartz, rare plag. feldspar, sericite flakes. Illitic clay with calcite & siderite.
Claystone: Grey, with silt-size quartz, rare plag. feldspar; rounded brown fragments ? Montmorillonitic clay

⑤ Siltstone: Grey-black, sandy and clayey. Muscovite & sericite flakes. Illitic clay, minor calcite. Pyrite and carbonaceous matter.

② Claystone: Grey-brown, silt-size rare quartz, and rounded brown fragments. Muscovite flakes. Montmorillonitic and illitic clay

⑤ Siltstone: Grey-brown, sandy, hard, grading into silty lithic sandstone. Quartz, rare oligoclase, lithic fragments. Illitic clay and calcite.

DESCRIPTION OF INTERPRETED LITHOLOGY

SILTSTONES & CLAYSTONES with SUBGREYWACKES

Siltstones: Grey, sandy, thickly bedded, with thin interbeds of lithic sandstone. Quartz, plag. feldspar, lithic fragments. Finely dispersed pyrite. Carbonaceous matter.

Claystones: Dark grey, with rare detrital quartz. MONTMORILLONITIC clay and minor chloritic clay. Scattered calcite crystals. Finely dispersed pyrite. Dispersed carbonaceous matter.

Sandy, pyritic, carbonaceous siltstones. — D11

4500'

Subgreywackes: Grey-brown, subangular, fine-grained, mod.-well sorted. Rare quartz, oligoclase; ab. VOLCANIC flow rock frag. Chlorite, calcite, pyrite.

Siltstone: Grey, pyritic. Silver grey phyllite below 4550'.

Dolerite: Green & brown, fine and medium grained. No free quartz. Interlocking of andesine laths. Brown augite crystals. Minor biotite. Minor chlorite. Iron oxide crystals. Patches of calcite.

Phyllite: Silver grey, and grey siltstone.

⑨ Rec 100' slightly gas-cut mud.

Subgreywackes: Grey-brown, thinly bedded, subangular, fine-grained and moderately sorted. No quartz, oligoclase (25%); ab. lithics of volcanic flow rock frag. and microcryst. siliceous fragments. Pellicular chlorite, CHLORITE cement and rare calcite. Minor dispersed pyrite.
At 4870' coarse-grained lithic sandstone replaced by calcite.

Siltstones: Grey, thinly bedded, sandy, grading into silty claystones. Dispersed pyrite and carbonaceous matter.

Pyritic Siltstones alternating with Subgreywackes. In Ss. rare quartz, ab. volc. fragments; chlorite & calcite cement. Pred. Volcanic rock provenance. — D12

5035'

Alternating SUBGREYWACKES, SILTSTONES, thin COALS, minor CLAYSTONES.

Claystones: Black, thinly bedded, silty. Rare quartz. Chloritic clay with finely dispersed carbonaceous matter. Scattered calcite crystals, pyrite specks.

Coal: Black, thin beds, vitreous, semi-anthracite.

Siltstones: Grey & brown, thinly bedded, sandy, grading into claystones. Mica flakes. Carbonaceous matter. Thinly laminated.

Thin Coal seams, Siltstones and Subgreywackes. In Ss. qz. absent, ab. volcanic frag. — D13

5296'

5320'

Subgreywackes: Green, grey & brown, with thin interbeds of siltstones, angular-subangular, fine to medium-grained, and mod. to well sorted. No quartz, oligoclase & albite; lithics of VOLCANIC flow rock frag., brown chloritized flow rock frag., microcryst. siliceous fragments. Chloritized muscovite. Pellicular chlorite, CHLORITE cement and calcite. Dispersed pyrite.

⑧ mod.-poor blow.

At 5560' fine-grained lithic sandstone replaced by calcite.

Subgreywackes & thin beds of siltstone. In Ss., qz. absent, ab. volc. frag.; chlorite, calcite cement. — D14

5620'

Siltstones: Grey-black, thickly bedded, sandy, becoming shaly towards the base. Quartz, plag. feldspar, lithic fragments. Sericite flakes. Chloritic clay with dispersed carbonaceous matter. Patches of calcite. Pyrite specks.

Subgreywackes: Grey, silty, ang.-subangular, fine-grained and moderately sorted. Straight ext. QUARTZ (40%), oligoclase; lithics of chloritized siliceous frag, microcryst. sil. frag., rare volcanic flow rock fragments. Chloritic clay. Pyrite specks and patches.

Siltstones & subordinate Subgreywackes. In Ss. quartz present. — D15

5870'

SILTSTONES with CLAYSTONES and minor SUBGREYWACKES

Siltstones: Grey-black, massive, sandy, clayey, with shaly horizons. Quartz-straight & undulose ext., rare plag. feldspar; lithics of microcryst. siliceous frag., and brown chloritic fragments. Muscovite and sericite flakes. ILLITIC and minor chloritic clay with dispersed carbonaceous matter. Patches of calcite. Dispersed pyrite as specks and patches.

Claystones: Brown & grey interbedded with siltstone. Silty, with quartz, rare feldspar, sericite flakes. Illitic clay with calcite and siderite patches. Grey Claystone with silt-size rounded brown fragments in MONTMORILLONITIC-type clay.

Siltstones: Grey-black, massive, sandy becoming clayey. Rare feldspar and lithic fragments. Muscovite flakes. Illitic clay & patches of calcite. Pyrite & carbonaceous matter. Claystone laminations. Micro & cross bedding.

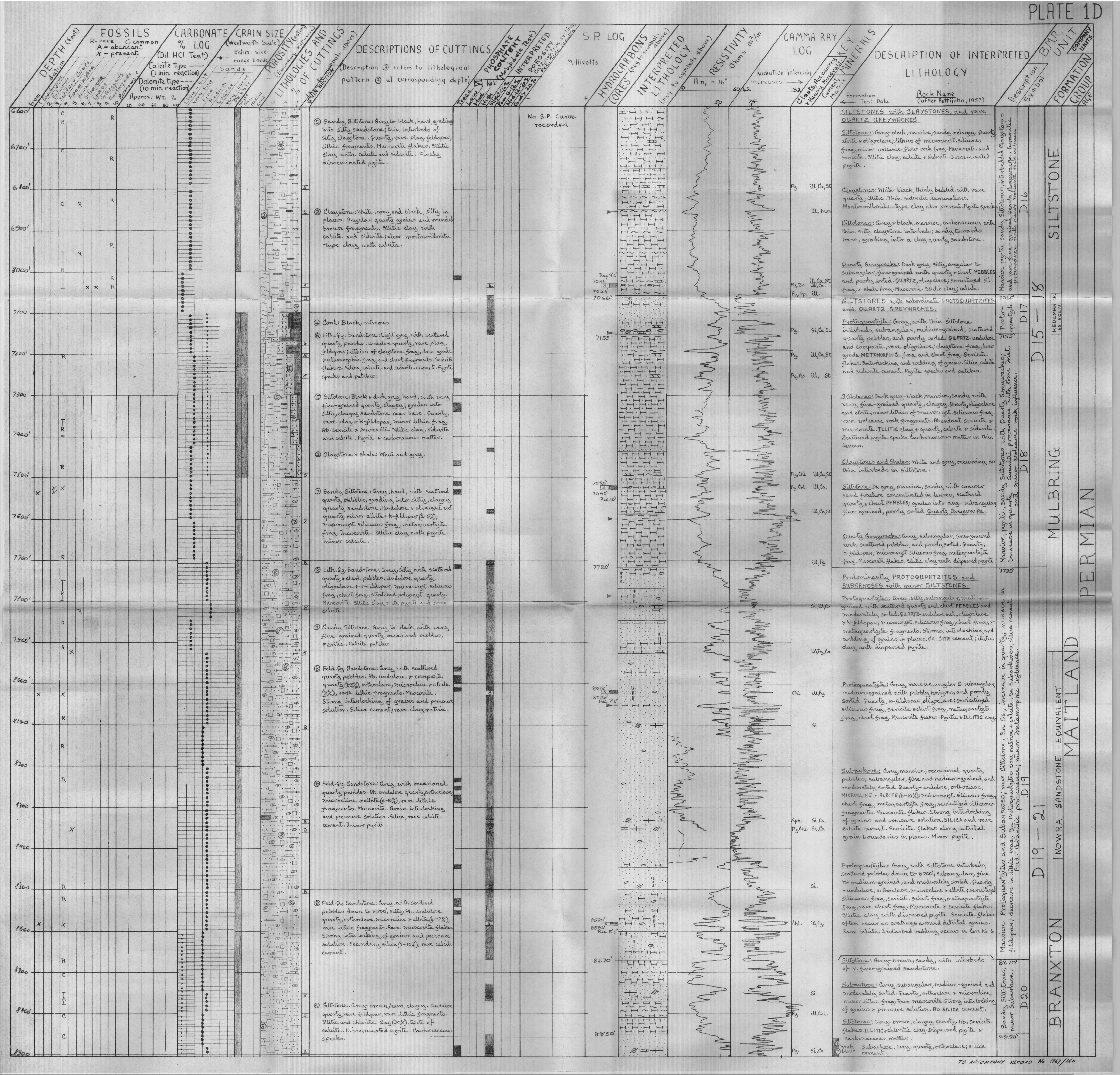
Claystone interbeds: Grey-brown, rare silt-size quartz and rounded brown fragments (? illite). Muscovite flakes. Illitic & montmorillonitic clay.

Subgreywacke: Grey-brown, silty, ang.-subangular v. fine-grained and moderately sorted. Illitic clay and patches of calcite.

Sandy pyritic Siltstones with interbedded Claystones and minor v. fine-grained Subgreywackes. In Siltstones, quartz, rare feldspar, decrease in lithic frag. Illitic clay. Granitic and volcanic rock provenance. — D16

TO ACCOMPANY RECORD No 1967/160

PLATE 1D



DESCRIPTIONS OF CUTTINGS

(Description ③ refers to lithological pattern ③ at corresponding depth.)

⑤ Sandy Siltstone: Grey to black, hard, grading into silty sandstone; thin interbeds of silty claystone. Quartz, rare plag. feldspar, lithic fragments. Muscovite flakes. Illitic clay with calcite and siderite. Finely disseminated pyrite.

② Claystone: White, grey and black, silty in places. Angular quartz grains and rounded brown fragments. Illitic clay with calcite and siderite; also montmorillonitic-type clay with calcite.

④ Coal: Black, vitreous.

⑥ Lith. Qz. Sandstone: Light grey, with scattered quartz pebbles. Undulose quartz, rare plag. feldspar; lithics of claystone frag., low grade metamorphic frag., and chert fragments. Sericite flakes. Silica, calcite and siderite cement. Pyrite specks and patches.

⑤ Siltstone: Black & dark grey, hard, with very fine-grained quartz, clayey; grades into silty, clayey sandstone near base. Quartz, rare plag. & K-feldspar, minor lithic frag. Ab. sericite & muscovite. Illitic clay, siderite and calcite. Pyrite & carbonaceous matter.

② Claystone & shale: White and grey.

⑦ Sandy Siltstone: Grey, hard, with scattered quartz pebbles, grading into silty, clayey quartz sandstone. Undulose & straight ext. quartz, minor albite + K-feldspar (2-5%); microcryst. siliceous frag., metaquartzite frag. Muscovite. Illitic clay with pyrite. Minor calcite.

⑧ Lith. Qz. Sandstone: Grey, silty with scattered quartz & chert pebbles. Undulose quartz, oligoclase + K-feldspar; microcryst. siliceous frag., chert frag., stretched polycryst. quartz. Muscovite. Illitic clay with pyrite and some calcite.

⑦ Sandy Siltstone: Grey to black, with very fine-grained quartz, occasional pebbles, pyritic. Calcite patches.

⑧ Feld. Qz. Sandstone: Grey, with scattered quartz pebbles. Ab. undulose & composite quartz (83%), orthoclase, microcline & albite (7%), rare lithic fragments. Muscovite. Strong interlocking of grains and pressure solution. Silica cement; rare clay matrix.

⑧ Feld. Qz. Sandstone: Grey, with occasional quartz pebbles. Ab. undulose quartz, orthoclase, microcline & albite (6-10%), rare lithic fragments. Muscovite. Grain interlocking and pressure solution. Silica, rare calcite cement. Minor pyrite.

⑧ Feld. Qz. Sandstone: Grey, with scattered pebbles down to 8700', silty. Ab. undulose quartz, orthoclase, microcline & albite (4-7%), rare lithic fragments. Rare muscovite flakes. Strong interlocking of grains and pressure solution. Secondary silica (5-10%), rare calcite cement.

⑤ Siltstone: Grey-brown, hard, clayey. Undulose quartz, rare feldspar, rare lithic fragments. Illitic and chloritic clay (30%). Spots of calcite. Disseminated pyrite. Carbonaceous specks.

DESCRIPTION OF INTERPRETED LITHOLOGY

Rock Name
(after Pettijohn, 1957)

SILTSTONES with CLAYSTONES, and rare QUARTZ GREYWACKES

Siltstones: Grey-black, massive, sandy & clayey. Quartz, albite & oligoclase; lithics of microcryst. siliceous frag., minor volcanic flow rock frag. Muscovite and sericite. Illitic clay; calcite & siderite. Disseminated pyrite.

Claystones: White-black, thinly bedded, with rare quartz; illitic. Thin sideritic laminations. Montmorillonitic-type clay also present. Pyrite specks.

Siltstones: Grey & black, massive, carbonaceous, with thin silty claystone interbeds; sandy towards base, grading into a clay quartz sandstone.

Quartz Greywacke: Dark grey, silty, angular to subangular, fine-grained with quartz & chert PEBBLES and poorly sorted. QUARTZ, oligoclase; sericitized sil. frag. & shale frag. Muscovite. Illitic clay; calcite.

SILTSTONES with subordinate PROTOQUARTZITES and QUARTZ GREYWACKES.

Protoquartzite: Grey, with thin siltstone interbeds, subangular, medium-grained, scattered quartz pebbles, and poorly sorted. QUARTZ-undulose and composite, rare oligoclase; claystone frag., low grade METAMORPHIC frag. and chert frag. Sericite flakes. Interlocking and welding of grains. Silica, calcite and siderite cement. Pyrite specks and patches.

Siltstones: Dark grey-black, massive, sandy with very fine-grained quartz, clayey. Quartz, oligoclase and albite; minor lithics of microcryst. siliceous frag., rare volcanic rock fragments. Abundant sericite & muscovite. ILLITIC clay + quartz, calcite & siderite. Scattered pyrite specks. Carbonaceous matter in thin lenses.

Claystones and Shales: White and grey, occurring as thin interbeds in siltstone.

Siltstone: Dk. grey, massive, sandy with coarser sand fraction concentrated in lenses, scattered quartz & chert PEBBLES; grades into ang.-subangular fine-grained, poorly sorted Quartz Greywacke.

Quartz Greywacke: Grey, subangular, fine-grained with scattered pebbles, and poorly sorted. Quartz, K-feldspar; microcryst. siliceous frag., metaquartzite frag. Muscovite flakes. Illitic clay with dispersed pyrite.

Predominantly PROTOQUARTZITES and SUBARKOSES with minor SILTSTONES.

Protoquartzites: Grey, silty, subangular, medium-grained with scattered quartz and chert PEBBLES and moderately sorted. QUARTZ-undulose ext., oligoclase & K-feldspar; microcryst. siliceous frag., chert frag., & metaquartzite fragments. Strong interlocking and welding of grains in places. CALCITE cement; illitic clay with dispersed pyrite.

Protoquartzite: Grey, massive, angular to subangular, medium-grained with pebbly horizons, and poorly sorted. Quartz, K-feldspar, oligoclase; sericitized siliceous frag., sericite schist frag., metaquartzite frag., chert frag. Muscovite flakes. Pyritic & ILLITIC clay.

Subarkose: Grey, massive, occasional quartz pebbles, subangular, fine and medium-grained, and moderately sorted. Quartz-undulose, orthoclase, MICROCLINE & ALBITE (6-10%); microcryst. siliceous frag., chert frag., metaquartzite frag., sericitized siliceous fragments. Muscovite flakes. Strong interlocking of grains and pressure solution. SILICA and rare calcite cement. Sericite flakes along detrital grain boundaries in places. Minor pyrite.

Protoquartzites: Grey, with siltstone interbeds, scattered pebbles down to 8700', subangular, fine to medium-grained, and moderately sorted. Quartz-undulose, orthoclase, microcline & albite; sericitized siliceous frag., sericite schist frag., metaquartzite frag., rare chert frag. Muscovite & sericite flakes. Illitic clay with dispersed pyrite. Sericite flakes often occur as coatings around detrital grains. Rare calcite. Disturbed bedding occurs in Core No. 6

Siltstone: Grey-brown, sandy, with interbeds of v. fine-grained sandstone.

Subarkose: Grey, subangular, medium-grained and moderately sorted. Quartz, orthoclase & microcline; minor lithic frag. Rare muscovite. Strong interlocking of grains & pressure solution. Ab. SILICA cement.

Siltstones: Grey-brown, clayey. Quartz. Ab. sericite flakes. ILLITIC & chloritic clay. Dispersed pyrite & carbonaceous matter.

Subarkose: Grey, quartz, orthoclase; silica cement.

B.M.R. UNIT – Description

D16: Massive pyritic sandy Siltstones, interbedded Claystones and rare fine-grained Quartz Greywacke. Granitic provenance with minor volcanic rock influence.

D17: Proto-quartzite

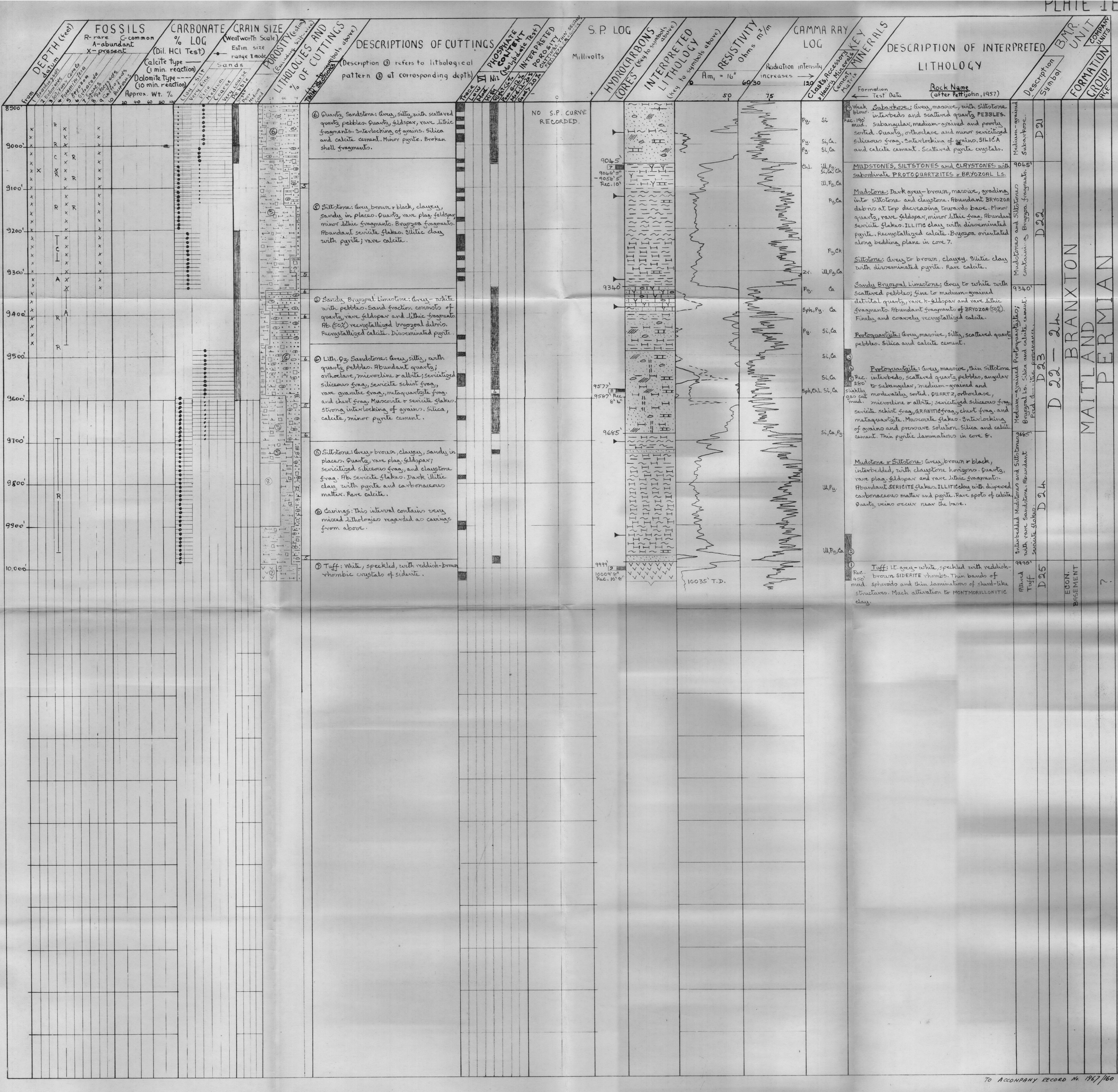
D18: Massive, pyritic, sandy Siltstones with Quartz Greywackes; increase in quartz. Granitic provenance with some met. and minor volcanic rock influence.

D19: Massive Protoquartzites and Subarkoses; rare Siltstone. In Ss., increase in quartz; increase in feldspar; decrease in lithic frag. In Protoquartzites clay matrix + calcite. In Subarkoses, silica cement. Pred. Granitic provenance; minor metamorphic influence.

D20: Sandy Siltstones; minor Subarkose.

TO ACCOMPANY RECORD No 1967/160

PLATE 1E



DESCRIPTIONS OF CUTTINGS

⑥ Quartz Sandstone: Grey, silty, with scattered quartz pebbles. Quartz, feldspar, rare lithic fragments. Interlocking of grains. Silica and calcite cement. Minor pyrite. Broken shell fragments.

⑤ Siltstone: Grey, brown & black, clayey, sandy in places. Quartz, rare plag. feldspar, minor lithic fragments. Bryozoa fragments. Abundant sericite flakes. Illitic clay with pyrite; rare calcite.

⑥ Sandy Bryozoal Limestone: Grey-white with pebbles. Sand fraction consists of quartz, rare feldspar and lithic fragments. Ab. (50%) recrystallized bryozoal debris. Recrystallized calcite. Disseminated pyrite.

⑥ Lith. Qz. Sandstone: Grey, silty, with quartz pebbles. Abundant quartz; orthoclase, microcline & albite; sericitized siliceous frag., sericite schist frag., rare granitic frag., metaquartzite frag. and chert frag. Muscovite & sericite flakes. Strong interlocking of grains. Silica, calcite, minor pyrite cement.

⑤ Siltstone: Grey & brown, clayey, sandy in places. Quartz, rare plag. feldspar; sericitized siliceous frag., and claystone frag. Ab. sericite flakes. Dark illitic clay with pyrite and carbonaceous matter. Rare calcite.

⑧ Cavings: This interval contains very mixed lithologies regarded as cavings from above.

⑦ Tuff: White, speckled, with reddish-brown rhombic crystals of siderite.

DESCRIPTION OF INTERPRETED LITHOLOGY

Subarkose: Grey, massive, with siltstone interbeds and scattered quartz PEBBLES. Subangular, medium-grained and poorly sorted. Quartz, orthoclase and minor sericitized siliceous frag. Interlocking of grains. SILICA and calcite cement. Scattered pyrite crystals.

MUDSTONES, SILTSTONES and CLAYSTONES with subordinate PROTOQUARTZITES & BRYOZOAL LS.

Mudstone: Dark grey-brown, massive, grading into siltstone and claystone. Abundant BRYOZOA debris at top decreasing towards base. Minor quartz, rare feldspar, minor lithic frag. Abundant sericite flakes. ILLITIC clay with disseminated pyrite. Recrystallized calcite. Bryozoa orientated along bedding plane in core 7.

Siltstone: Grey to brown, clayey. Illitic clay with disseminated pyrite. Rare calcite.

Sandy Bryozoal Limestone: Grey to white with scattered pebbles; fine to medium-grained detrital quartz, rare K-feldspar and rare lithic fragments. Abundant fragments of BRYOZOA (50%). Finely and coarsely recrystallized calcite.

Protoquartzite: Grey, massive, silty, scattered quartz pebbles. Silica and calcite cement.

Protoquartzite: Grey, massive, thin siltstone interbeds, scattered quartz pebbles, angular to subangular, medium-grained and moderately sorted. QUARTZ, orthoclase, microcline & albite; sericitized siliceous frag., sericite schist frag., GRANITIC frag., chert frag. and metaquartzite. Muscovite flakes. Interlocking of grains and pressure solution. Silica and calcite cement. Thin pyritic laminations in core 8.

Mudstone & Siltstone: Grey, brown & black, interbedded, with claystone horizons. Quartz, rare plag. feldspar and rare lithic fragments. Abundant SERICITE flakes. ILLITIC clay with dispersed carbonaceous matter and pyrite. Rare spots of calcite. Quartz veins occur near the base.

Tuff: Lt. grey-white, speckled with reddish-brown SIDERITE rhombs. Thin bands of spheroids and thin laminations of shard-like structures. Much alteration to MONTMORILLONITIC clay.

TO ACCOMPANY RECORD No. 1967/160

WELL NAME, Nº.: DURAL SOUTH Nº1
OPERATING Co.: SHELL DEVELOPMENT (Austr.) Pty. Ltd.
WELL LOCATION
Lat.: 33° 42' 37" S. Long.: 151° 01' 02" E
Basin: Sydney Basin
State: N.S.W.
Tenement No. P.E.L. 102 and 103.
1:250,000 Sheet Nº SI 56/5

ELEVATION (A.S.L.)
: Ground Level 635 ft.
: R.T. Datum 649 ft.

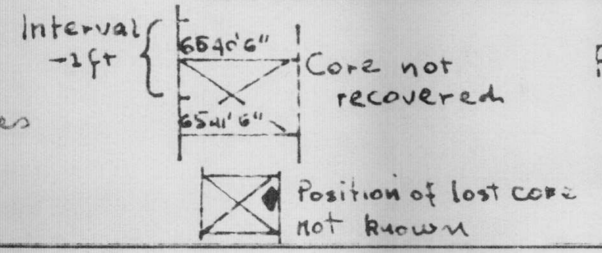
SAMPLE STORAGE
: B.M.R. Canberra
: N.S.W. Mines Dept., Sydney

PETROGRAPHIC CORE LOG DURAL SOUTH (SHELL) No. 1.

Geology by: P.J. HAWKINS and S. OZIMIC

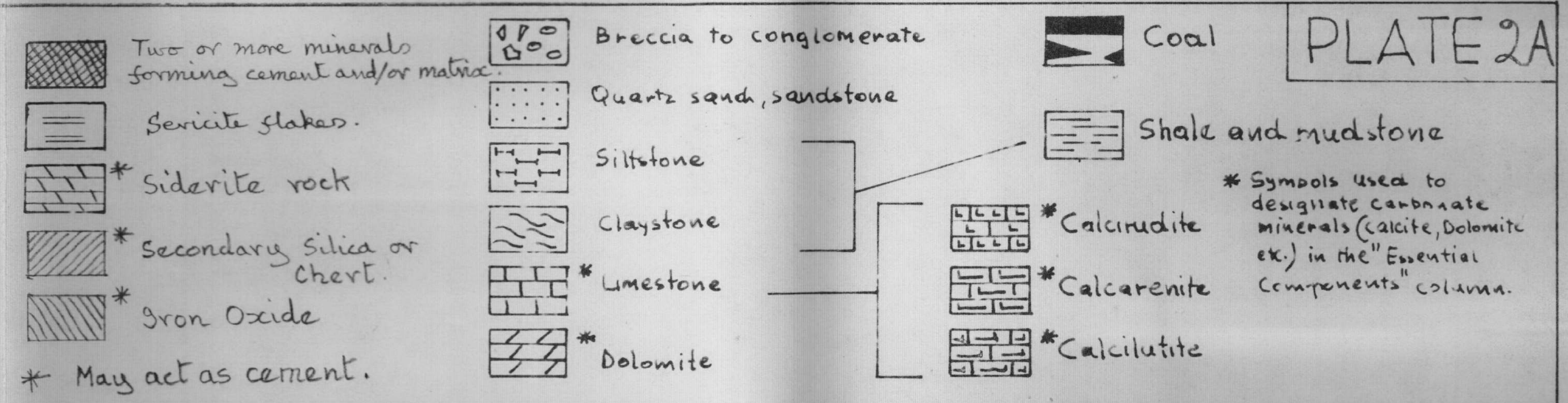
PLATE 2A

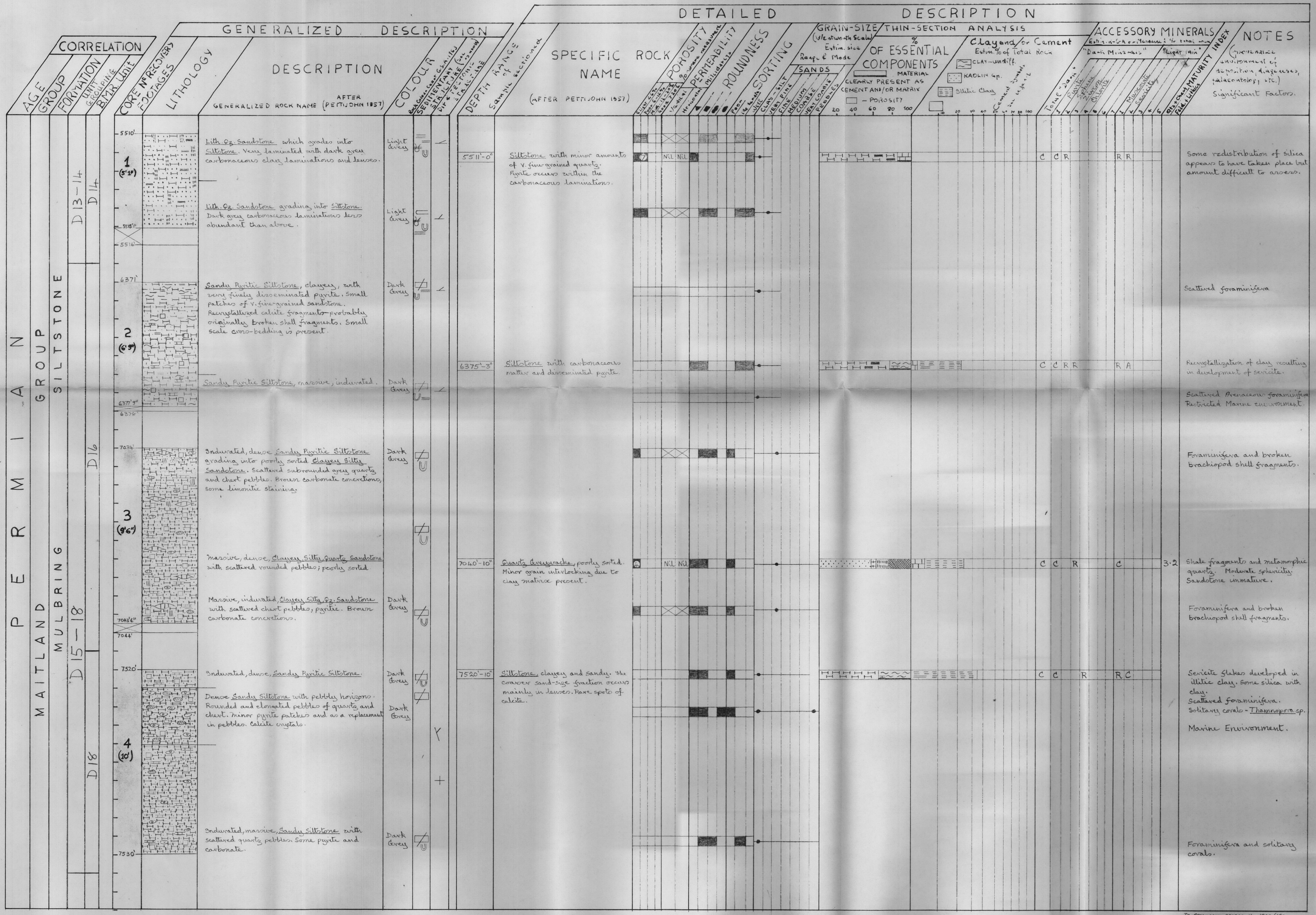
N.B. No porosity measurements are shown for silt-size sediments. Porosities shown are from Pet. Tech. analyses, and compromise figures from macroscopic and thin section work.



Porosity (estimated)
S - slight <6%
P Poor 6–12%
M Medium 12–20%
G Good >20%

Abundance (estimated)
R - rare <1%
C - common 1–3%
A - abundant 3–5%





CORE Nº RECOVERY FOOTAGES	GENERALIZED DESCRIPTION GENERALIZED ROCK NAME (AFTER PETTIJOHN 1957)	COLOUR	DEPTH RANGE of Sample sectioned	SPECIFIC ROCK NAME (AFTER PETTIJOHN 1957)	MATURITY INDEX	NOTES (Interpretive environment of deposition, diagenesis, palaeontology etc.) Significant Factors.
1 (5'1") 5510'	Lith. Qz. Sandstone which grades into Siltstone. Very laminated with dark grey carbonaceous clay laminations and lenses.	Light Grey	5511'-0"	Siltstone with minor amounts of v. fine-grained quartz. Pyrite occurs within the carbonaceous laminations.		Some redistribution of silica appears to have taken place but amount difficult to assess.
5515'1" 5516'	Lith. Qz. Sandstone grading into Siltstone. Dark grey carbonaceous laminations less abundant than above.	Light Grey				
2 (6'9") 6371'	Sandy Pyritic Siltstone, clayey, with very finely disseminated pyrite. Small patches of v. fine-grained sandstone. Recrystallized calcite fragments - probably originally broken shell fragments. Small scale cross-bedding is present.	Dark Grey				Scattered foraminifera
			6375'-3"	Siltstone with carbonaceous matter and disseminated pyrite.		Recrystallization of clay resulting in development of sericite.
6377'9" 6378'	Sandy Pyritic Siltstone, massive, indurated.	Dark Grey				Scattered Arenaceous foraminifera Restricted Marine environment.
3 (9'6") 7034'	Indurated, dense Sandy Pyritic Siltstone grading into poorly sorted Clayey Silty Sandstone. Scattered subrounded grey quartz and chert pebbles. Brown carbonate concretions, some limonitic staining.	Dark Grey				Foraminifera and broken brachiopod shell fragments.
	Massive, dense, Clayey, Silty, Quartz Sandstone with scattered rounded pebbles; poorly sorted.		7040'-10"	Quartz Greywacke, poorly sorted. Minor grain interlocking due to clay matrix present.	3.2	Shale fragments and metamorphic quartz. Moderate sphericity. Sandstone immature.
7043'6" 7044'	Massive, indurated, Clayey, Silty, Qz. Sandstone with scattered chert pebbles, pyritic. Brown carbonate concretions.	Dark Grey				Foraminifera and broken brachiopod shell fragments.
4 (10') 7520'	Indurated, dense, Sandy Pyritic Siltstone.	Dark Grey	7520'-10"	Siltstone, clayey and sandy. The coarser sand-size fraction occurs mainly in lenses. Rare spots of calcite.		Sericite flakes developed in illitic clay. Some silica with clay. Scattered foraminifera. Solitary corals - Thamnopora sp. Marine Environment.
	Dense Sandy Siltstone with pebbly horizons. Rounded and elongated pebbles of quartz and chert. Minor pyrite patches and as a replacement in pebbles. Calcite crystals.	Dark Grey				
7530'	Indurated, massive, Sandy Siltstone with scattered quartz pebbles. Some pyrite and carbonate.	Dark Grey				Foraminifera and solitary corals.

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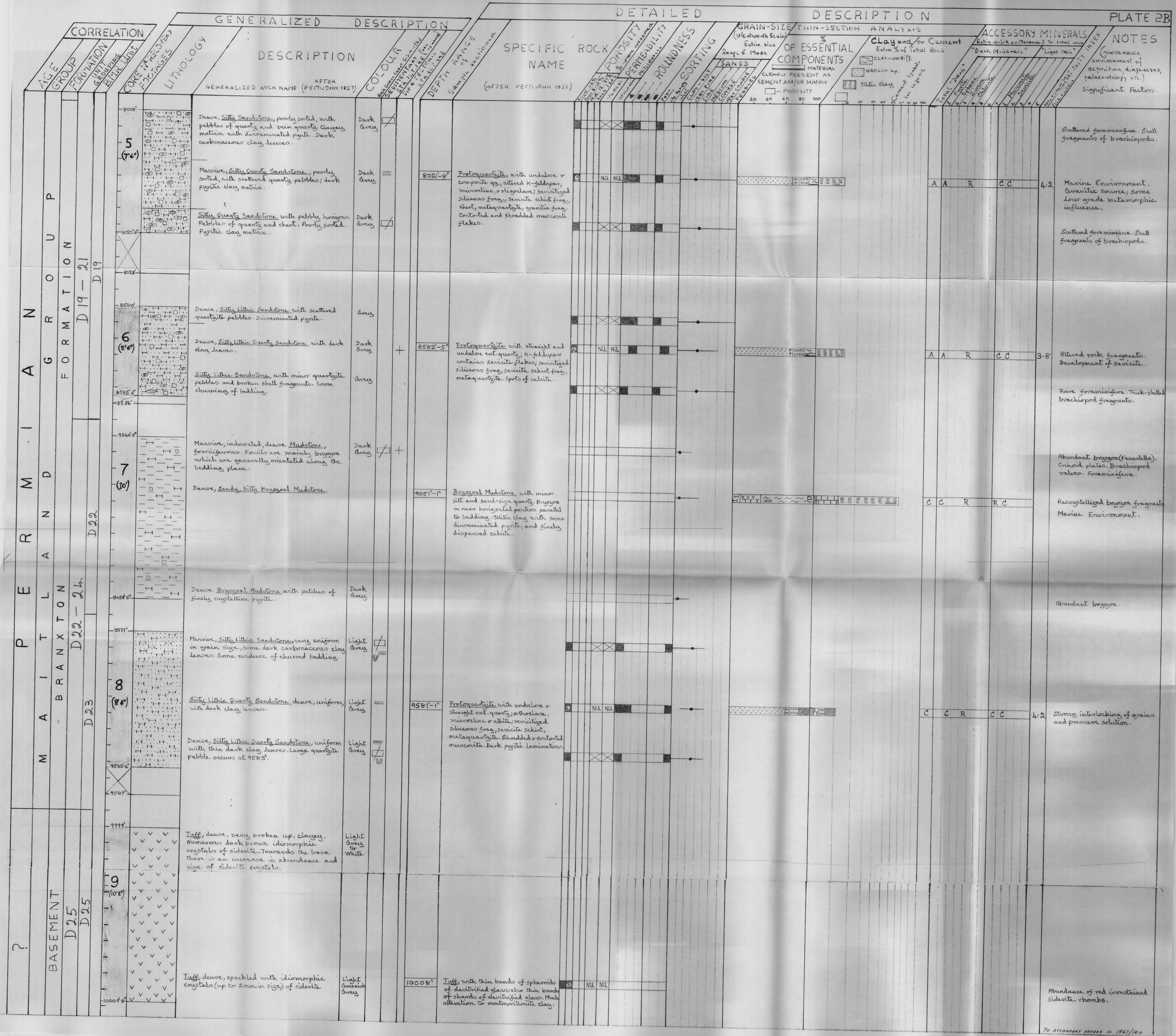
PLATE 2B



CORE No RECOVERED FOOTAGES	DESCRIPTION GENERALIZED ROCK NAME (AFTER PETTIJOHN 1957)	COLOUR	DEPTH RANGE of Sample sectioned	SPECIFIC ROCK NAME (AFTER PETTIJOHN 1957)	ACCESSORY MINERALS	MATURITY INDEX	NOTES (provenance environment of deposition, diageneses, palaeontology etc.) Significant Factors.
5 (7'6") 8018'–8025'6"	Dense, Silty Sandstone, poorly sorted, with pebbles of quartz and vein quartz. Clayey matrix with disseminated pyrite. Dark carbonaceous clay lenses.	Dark Grey					Scattered foraminifera. Shell fragments of brachiopods.
	Massive, Silty Quartz Sandstone, poorly sorted, with scattered quartz pebbles; dark pyritic clay matrix.	Dark Grey	8021'-8"	Protoquartzite, with undulose & composite qz., altered K-feldspar, microcline, & oligoclase; sericitized siliceous frag., sericite schist frag., chert, metaquartzite, granitic frag. Contorted and shredded muscovite flakes.	A A R C C	4.2	Marine Environment. Granitic source; some low grade metamorphic influence.
	Silty Quartz Sandstone with pebbly horizons. Pebbles of quartz and chert. Poorly sorted. Pyritic clay matrix.	Dark Grey					Scattered foraminifera. Shell fragments of Brachiopods.
6 (5'6") 8580'–8585'6"	Dense, Silty Lithic Sandstone with scattered quartzite pebbles. Disseminated pyrite.	Grey					
	Dense, Silty Lithic Quartz Sandstone with dark clay lenses.	Dark Grey	8582'-5"	Protoquartzite with straight and undulose ext. quartz; K-feldspar contains sericite flakes; sericitized siliceous frag, sericite schist frag., metaquartzite. Spots of calcite.	A A R C C	3.8	Altered rock fragments. Development of sericite.
	Silty Lithic Sandstone with minor quartzite pebbles and broken shell fragments. Some churning of bedding.	Grey					Rare foraminifera. Thick-shelled brachiopod fragments.
7 (10') 9048'5"–9058'5"	Massive, indurated, dense Mudstone, fossiliferous. Fossils are mainly bryozoa which are generally orientated along the bedding plane.	Dark Grey					Abundant bryozoa (Fenestella). Crinoid plates. Brachiopod valves. Foraminifera.
	Dense, Sandy, Silty Bryozoal Mudstone.		9051'-1"	Bryozoal Mudstone with minor silt and sand-size quartz. Bryozoa in near horizontal position parallel to bedding. Illitic clay with some disseminated pyrite, and finely dispersed calcite.	C C R R C		Recrystallized bryozoa fragments. Marine Environment.
	Dense Bryozoal Mudstone with patches of finely crystalline pyrite.	Dark Grey					Abundant bryozoa.
8 (8'4") 9577'–9585'4"	Massive, Silty Lithic Sandstone, very uniform in grain size, some dark carbonaceous clay lenses. Some evidence of churned bedding.	Light Grey					
	Silty Lithic Quartz Sandstone, dense, uniform, with dark clay lenses.	Light Grey	9581'-1"	Protoquartzite with undulose & straight ext. quartz; orthoclase, microcline & albite; sericitized siliceous frag., sericite schist, metaquartzite. Shredded & contorted muscovite. Dark pyritic laminations.	C C R C C	4.2	Strong interlocking of grains and pressure solution.
	Dense, Silty Lithic Quartz Sandstone, uniform with thin dark clay lenses. Large quartzite pebble occurs at 9583'.	Light Grey					
9 (10'8") 9999'–10009'8"	Tuff, dense, very broken up, clayey. Numerous dark brown idiomorphic crystals of siderite. Towards the base there is an increase in abundance and size of siderite crystals.	Light Grey to White					
	Tuff, dense, speckled with idiomorphic crystals (up to 2mm in size) of siderite	Light Greenish Grey	10008'	Tuff, with thin bands of spheroids of devitrified glass; also thin bands of shards of devitrified glass. Much alteration to montmorillonite clay.			Abundance of red ironstained siderite rhombs.

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