

NORTHERN TERRITORY GEOLOGICAL SURVEY

TECHNICAL REPORT

GS 96/004

**Helen Springs stratigraphic drilling 1996 -
NTGS96/1 Nilly Waterhole**

by

PD Kruse

DEPARTMENT OF MINES AND ENERGY

November 1996

DRILLING PROPOSAL - HELEN SPRINGS

January 1996

Background

NTGS commenced fieldwork in the Helen Springs 1:250 000 sheet area in 1994 with the intention of producing a second-generation geological map and explanatory notes, complementing previous mapping in the Tennant Creek sheet area to the south. The Helen Springs sheet area consists of boldly outcropping Proterozoic sandstone and minor mudstone and conglomerate (Tennant Creek Inlier) in the west, and intermittently outcropping, gently dipping Cambrian sedimentary units of the western Georgina Basin in the centre and east.

The Proterozoic succession is well catered for by existing company cored drilling, but drilling to date in the Cambrian succession has been woefully inadequate. Only two holes have been drilled in the northwestern Georgina Basin (Barkly Sub-basin), neither of them fully cored (see below). There is thus a need for a cored reference hole for the Sub-basin.

Drilling objectives

It is proposed to drill a fully cored stratigraphic hole in the Helen Springs sheet area in order to intersect the Helen Springs Volcanics (latest Neoproterozoic or Early Cambrian) and Gum Ridge Formation (early Middle Cambrian). The former unit includes basic volcanics and sandstone, the latter, fossiliferous chertified limestone and shale. Justification is as follows:

*The hole would provide a stratotype section for the Helen Springs Volcanics and Gum Ridge Formation. Despite their longevity, these units have not been defined to date, and no suitable section exists at surface due to paucity of outcrop and absence of exposed formation contacts.

*The hole offers the possibility of providing a biostratigraphic reference section for the Barkly Sub-basin, allowing enhanced correlation with the petroleum-prospective Middle Cambrian succession in the southern Georgina Basin.

*A complete record of sedimentary and volcanic lithology and structure will permit more meaningful interpretation of depositional environments than is possible from the weathered, altered and chertified outcrops available. This may assist in delineating potential metallic and non-metallic resources (e.g., phosphate: the target units are correlative with rich phosphate deposits in the Thornton Limestone of the eastern Georgina Basin, Queensland).

*Contingently, the lithological-biostratigraphic reference section so obtained may enhance the general petroleum prospectivity of the Georgina Basin. The Gum Ridge Formation is correlative with the Arthur Creek Formation in the highly prospective southern part of the basin; that formation is considered the most promising known source, reservoir and seal unit in the entire basin, and has demonstrated oil shows (NTGS 1994). Continuous coring of the Gum Ridge Formation may allow recognition of aerobic and anaerobic facies (the latter considered to be an excellent potential source) as in the Arthur Creek Formation; this is not possible from chertified outcrops. The prospectivity of the Barkly Sub-basin may thus be enhanced. "The northern Georgina Basin remains essentially unexplored"; "This northern area, should not, however, be

totally disregarded" (NTGS 1994: 23, 93).

*The hole would permit assessment of groundwater suitability in the succession below the productive Anthony Lagoon beds and Wonarah beds, i.e., in the Gum Ridge Formation and the basal sandstone of the Helen Springs Volcanics. If the volcanics are subaerial, this will imply an eroded top for the basal sandstone, rendering it amenable for groundwater movement.

Existing drillholes

Only two holes have been drilled in the Barkly Sub-basin, neither of them adequately cored (see Georgina Basin map and logs). Both intersected Middle Cambrian units slightly younger than those targeted by the proposed hole.

*Brunette Downs-1, drilled by Papuan Apinaipi Petroleum Co Ltd in 1964. Intersected Anthony Lagoon beds (320 m) above Mesoproterozoic (302 m); total depth 622 m. Eleven short core samples totalling 18 m were taken.

*Frewena-1, drilled by Barkly Oil Co Pty Ltd in 1965. Intersected 312 m of Wonarah beds (total depth). Two short core samples totalling 2 m taken.

Proposed drillhole

Location: Central and southeastern Helen Springs 1:250 000 sheet area as shown on accompanying map.

Depth and cost: Estimated total depth 300 m+, full core entire depth, comprising initial 30 m at HQ size (core diameter 63.5 mm) and the remainder at NQ size (core diameter 47.6 mm). Estimated cost at \$120/metre: \$36 000. Anticipated intersections based in part on thicknesses of equivalent units in adjoining basins:

0-20 m	Anthony Lagoon beds
20-200 m	Gum Ridge Formation
200-280 m	Helen Springs Volcanics (upper volcanic unit)
280-300 m	Helen Springs Volcanics (basal sandstone unit)
300 m+	Mesoproterozoic

Hole to terminate immediately below base of Helen Springs Volcanics basal sandstone unit (recognised as initial conglomeratic interval).

Proposed study techniques:

*Downhole temperature logging will assist in the recognition of individual groundwater aquifers, permitting assessment of the pre-Anthony Lagoon beds succession for groundwater suitability

*Downhole gamma-ray, resistivity and self-potential logging will assist in lithological subdivision and the recognition of individual intervals elsewhere

*Thin sectioning of selected core samples for petrological and sedimentological study in conjunction with standard core logging

*Systematic acid digestion of selected core samples for biostratigraphic study.

Timing

The proposed hole should be drilled as soon as possible in the 1996 field season, to ensure incorporation of results into NTGS publications currently in preparation (Helen Springs explanatory notes and NTGS Report 9 on Georgina Basin-Wiso Basin palaeontology).

Reference

Northern Territory Geological Survey, 1994- Petroleum basin study. Georgina Basin. Prepared by Questa Australia Pty Ltd. *Northern Territory Government Printer, Darwin.*

January 1996

Fig.1

From NTGS (1994), p.33.
Existing (uncored) drillholes, northern Georgina Basin

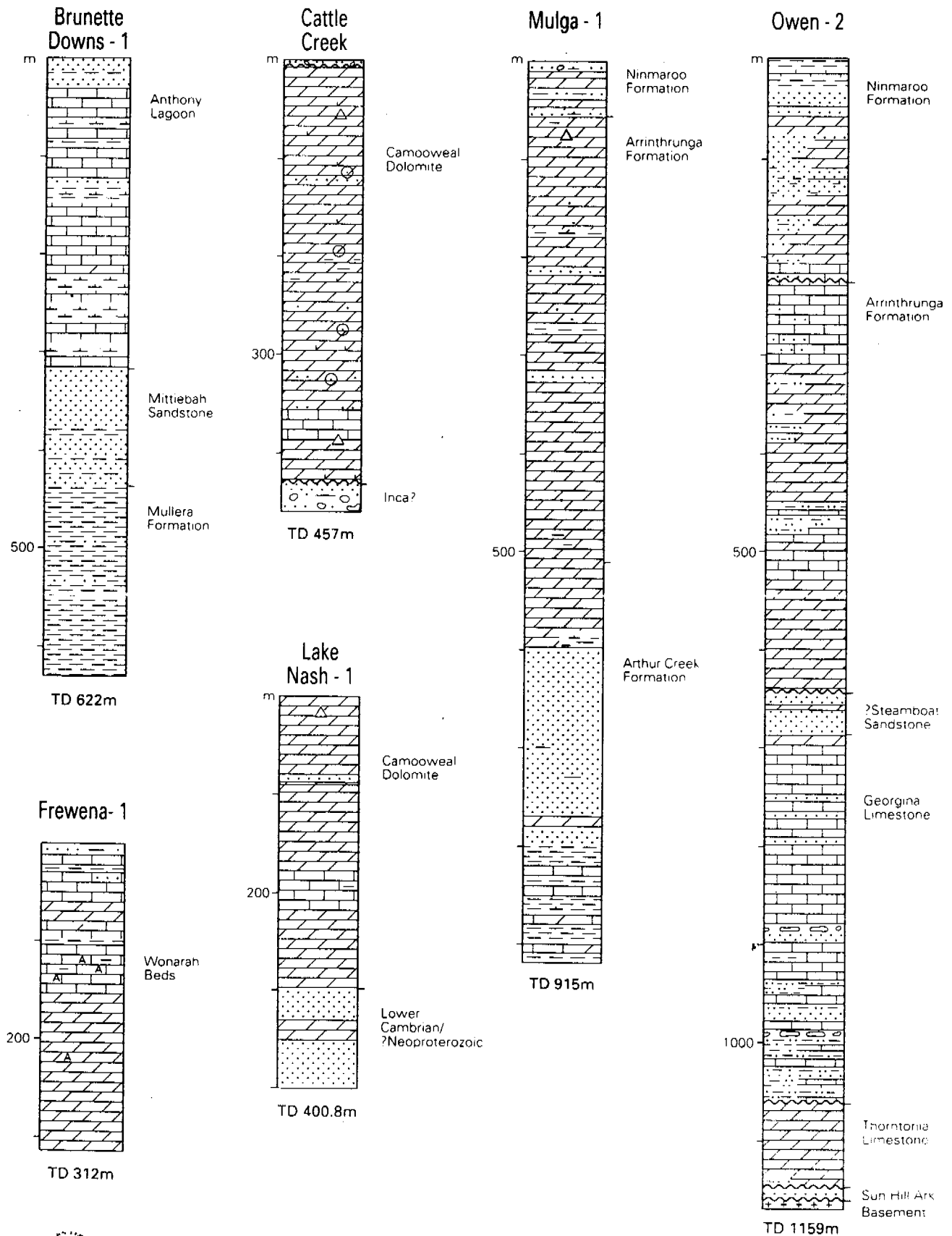
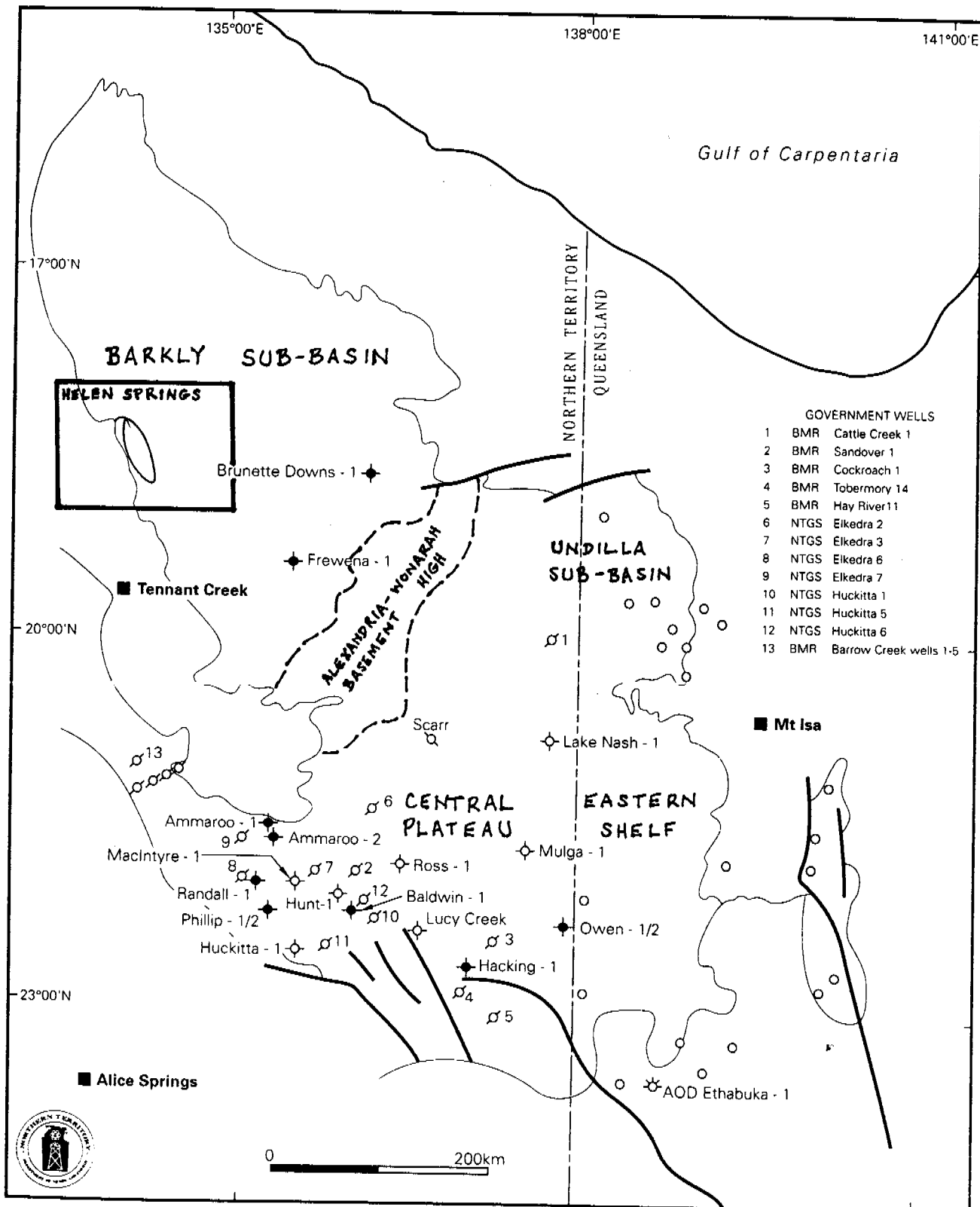


Figure 13a Well Lithologies: Brunette Downs-1, Cattle Creek, Mulga-1, Owen-2, Frewena-1, Lake Nash-1

5

Fig. 2 From NTGS (1994), p.16 (modified).
Existing drillholes, Georgina Basin



Note: Well locations are not precise

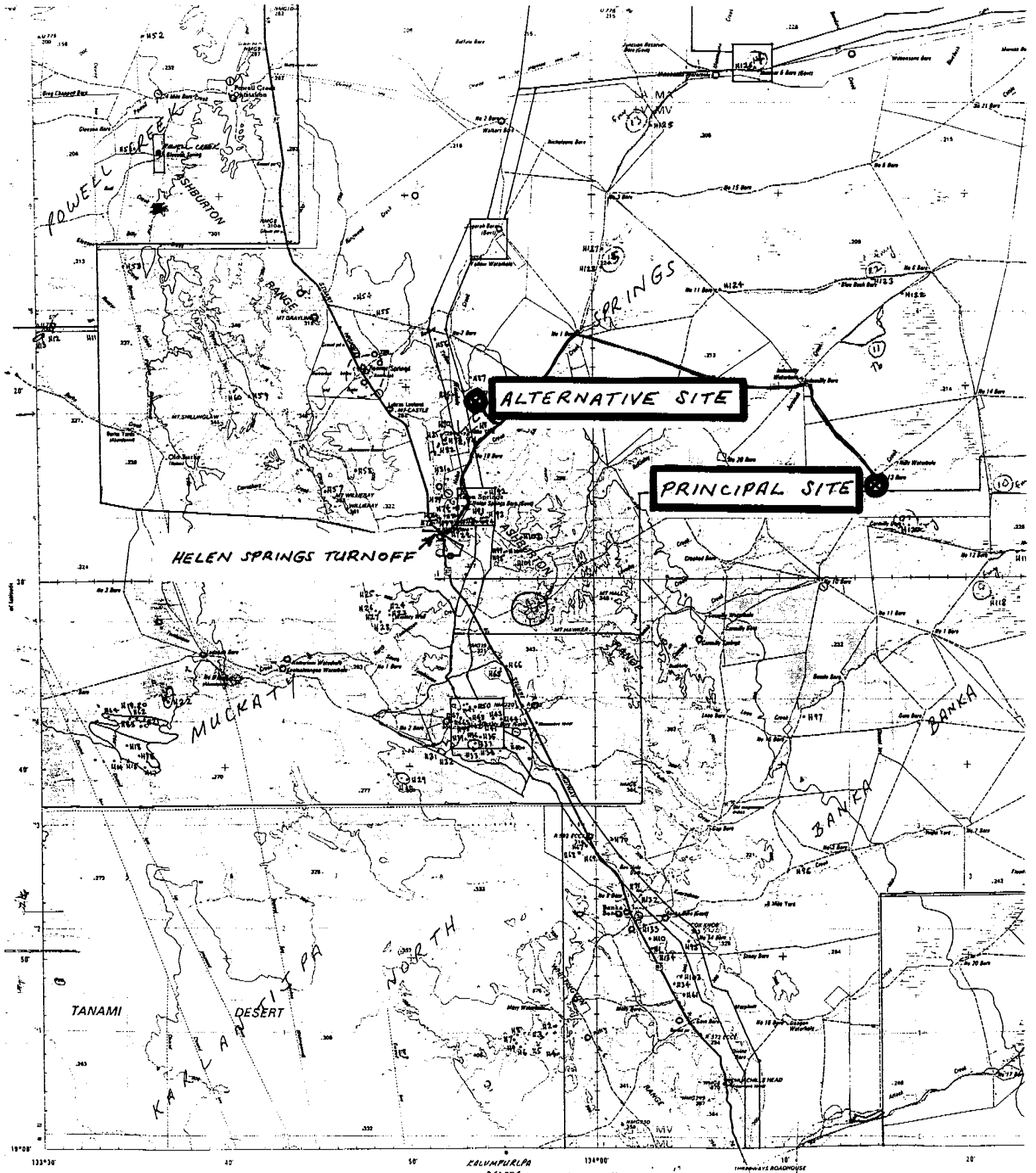
Figure 5 Location of Wells

- ⊕ Company exploration wells
- ◆ Company stratigraphic wells
- ♂ BMR / NTGS stratigraphic wells
- Company wells - Queensland
- ⊞ Company mineral exploration well

Fig. 3 Location of principal and alternative drillsites, Helen Springs.

Principal drilling site is 62 km from Stuart Highway at Helen Springs turnoff.
Alternative drilling site is 18 km from Stuart Highway at Helen Springs turnoff.

HELEN SPRINGS 1:250 000



DRILLING RESULTS - NTGS96/1 NILLY WATERHOLE November 1996

Background

The preceding drilling proposal was submitted in January 1996 and subsequently accepted, with an allocated budget of \$45 000.

Following field inspections by PD Kruse in June-July 1996, a principal drilling site was selected at No. 13 Bore on Helen Springs, adjacent to Nilly Waterhole. This site was chosen as it was considered sufficiently up-section from the surface Gum Ridge Formation-Anthony Lagoon beds boundary for any drillhole to intersect a representative portion (20-50 m) of the basal Anthony Lagoon beds before entering the Gum Ridge Formation. As well, the site lay within an area thought to be underlain by Helen Springs Volcanics as delineated by geophysical modelling undertaken by Roger Clifton (NTGS, Darwin).

In anticipation of the possibility of failure to intersect the Helen Springs Volcanics at the principal drillsite, an alternative site to the north of 5 Mile Yard on Helen Springs was identified. At this low mesa site, well exposed Cretaceous sandstone rested directly on Helen Springs Volcanics.

A drilling tender document was prepared for the NTGS by the Contract Services Branch, Asset Services Division, NT Department of Transport & Works. Tenders were called, closing on 28 August 1996. Gorey & Cole Drillers Pty Ltd, Alice Springs was the successful tenderer.

Drilling performance

Drilling was undertaken using a UDR 1000 rig under the responsibility of M Tomlin of Gorey & Cole Drillers Pty Ltd. Access to the drillsite was by cooperation of John O'Kane, manager of Helen Springs property. PD Kruse was drilling Supervisor. Drilling history was as follows:

7 October	Contact with rig and crew at Renner Springs; travel to principal drilling site (total distance 82 km); establishment
8 October	Reaming to 12 m depth; commenced HQ coring
9-11 October	Continued HQ coring to 141 m depth, reaching upper Gum Ridge Formation
12-15 October	NQ coring to total depth at 270 m; downhole geophysical logging
16 October	Cementing at formation boundaries; packing up; site rehabilitation
17 October	Departed site

Excellent core recovery was achieved for all but the Recent soil cover. Drilling intersections were:

0-34 m	Recent clay (black soil)
34-84 m	basal Anthony Lagoon beds (thickness 50 m)
84-235 m	Gum Ridge Formation (thickness 151 m)

235-242 m	Helen Springs Volcanics (thickness 7 m)
242-244 m	Helen Springs Volcanics basal sandstone (thickness 2 m)
244-270 m	Mesoproterozoic sandstone (thickness 26 m+)

There was no necessity for recourse to the alternative drilling site.

Daily drilling performance is graphed in Fig. 4. No significant drilling problems were encountered. Average drill penetration for the period 8-15 October was 33.7 m per day. A maximum daily penetration of 54 m was achieved on 11 October, in upper Gum Ridge Formation.

Downhole geophysics

Downhole geophysical logging was conducted on the afternoon of 15 October by Phil Turner and Bob Paul of the NT Department of Lands, Planning and Environment, Alice Springs. Self-potential, SPR, gamma-ray, temperature and caliper logging was completed. Preliminary logs are shown in Fig. 5.

Budget

Total cost for the drillhole was \$42 265, giving a cost per metre of \$156.71.

Drilling objectives

The objectives set out in the drilling proposal of January 1996 were generally attained.

*The hole meets all requirements of a stratotype section for the Gum Ridge Formation, Helen Springs Volcanics and Helen Springs Volcanics basal sandstone. In fact the latter unit (as a newly named member of the Helen Springs Volcanics) will be defined using outcrop boundaries.

*Core obtained for the Gum Ridge Formation ranges in preservation from pristine limestone to partially dolomitised limestone, and is thus generally amenable to acetic acid digestion for microfossils. As well, all rock types can be split for trilobites and other fossils. The hole will thus provide a much-needed, otherwise unobtainable biostratigraphic reference section for the Barkly Sub-basin.

*The state of preservation of all intersected Cambrian units is excellent, so providing a complete record of sedimentary and volcanic lithology through the interval (Fig. 6). This will allow a meaningful interpretation of depositional environments. No phosphate was intersected, but some minor visible sulphide is locally present.

*The Cambrian interval is too thin to promote hydrocarbon generation in the immediate region, but the hole can assist exploration by providing a useful reference section for comparison with other areas of the Georgina Basin.

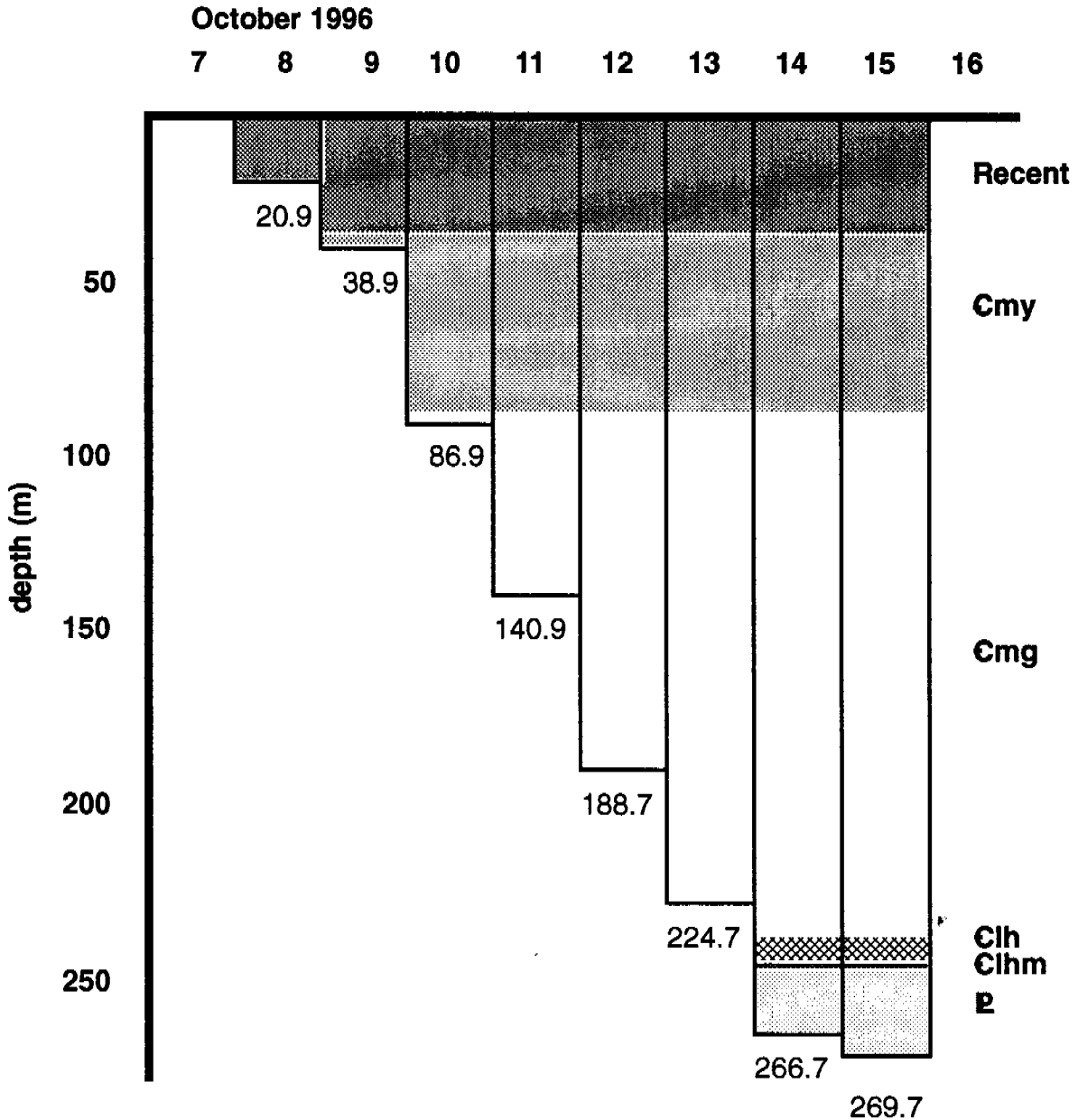
*As water-assisted drilling was employed throughout, no assessment of the stratigraphic position or flow rates of aquifers was possible. However, logging of porosity should be an aid in aquifer delineation.

Some 25 samples have been selected for thin sectioning, and a programme of acid digestion for microfossils is under way.

November 1996

Fig. 4 NTGS96/1 Nilly Waterhole - daily drilling performance

C_{my} = Anthony Lagoon beds
 C_{mg} = Gum Ridge Formation
 Cl_h = Helen Springs Volcanics
 Cl_{hm} = Helen Springs Volcanics basal sandstone
 P = Mesoproterozoic sandstone

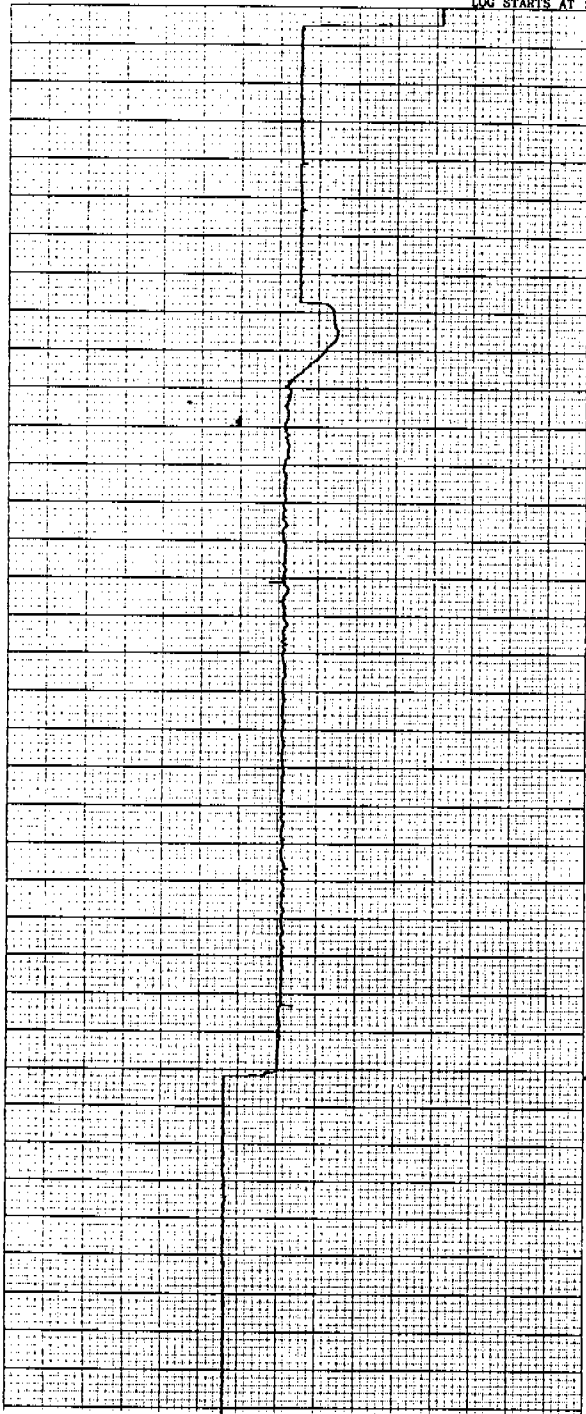


POWER AND WATER AUTHORITY								
HOLE NO: NTGS96/1								
LOGGED: 15/10/96 at 13:22								
COMPANY PAWA WRB AREA HELEN SPRINGS PROSPECT CORE HOLE OPERATOR P TURNER								
## DRILLING DATA ##								
PERM DAT - ELEV - HOLE POS - HOLE DIA - DEPTH 273 CASE-TYP NIL CASE-DTH - CASE-DIA - CASE-THK -								
#### FLUID DATA ####								
FLD TYPE MUD FLUIDLEV - LOGTYPE TD-5 APROX SP 6								
TOOL: T008--3 ARM CALLIPER 40 Serial Number: 1245 Spacer (cm) : n/a								
CHANNEL DATA								
CHANNEL	AMPLITUDE	RANGE	CHART	AREA	SENSOR OFFSET	FILTER CNST	PLOT TYPE	
1 - CALLIPER 40	1.00	- 6.00	2.0	- 12.0	97	0.0	1	
Calibration Data								
CHANNEL	slope		offset		C1	C2	C3	C4
1 - CALLIPER 40	INCHES	0.007244	-12.3573		4.134	2276	5.906	2521
LOG FILENAME: NTGS96-1C								
Logged: UP by DEPTH Interval 5 cm								

SCALE: 1 TO 500
without
DEPTH CORRECTION

CALLIPER 40
INCHES

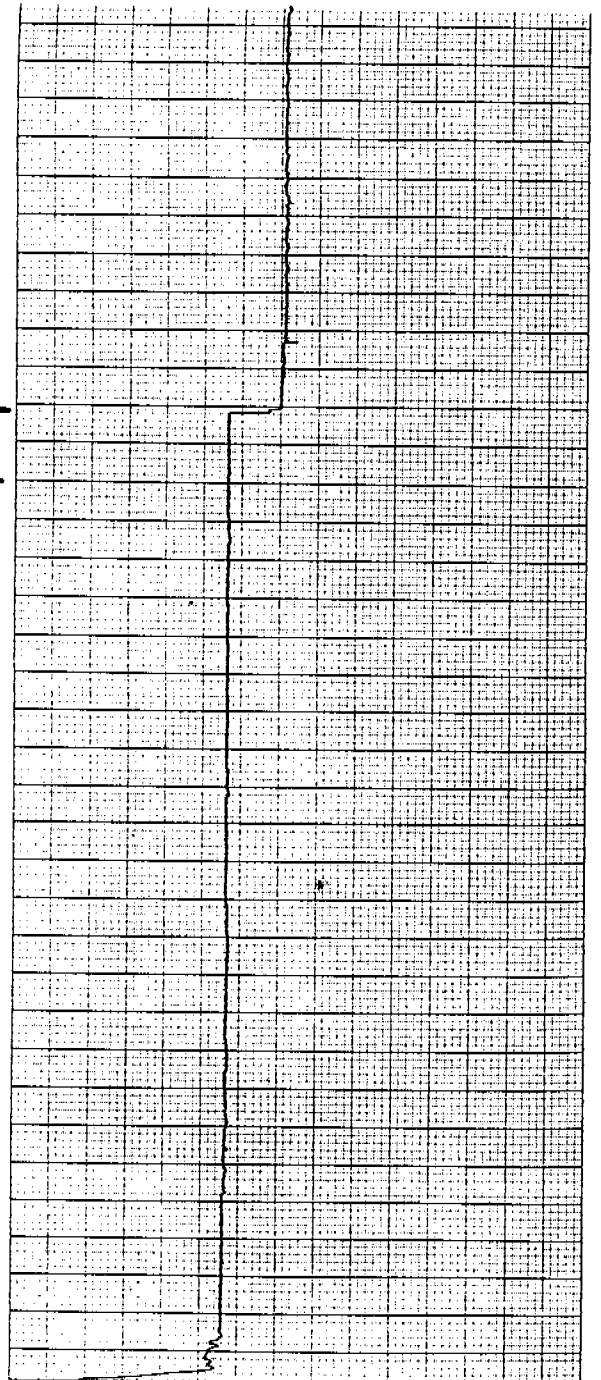
LOG STARTS AT : 0.02m.



CALIPER

← BOTTOM OF HW CASING

← BOTTOM OF HQ CASING



LOG ENDS AT : 268.

POWER AND WATER AUTHORITY

HOLE NO: NTGS96/1

LOGGED: 15/10/96 at 14:42

COMPANY PAWA WRB
 AREA HELEN SPRINGS
 PROSPECT CORE HOLE
 OPERATOR P TURNER

DRILLING DATA

PERM DAT -
 ELEV -
 HOLE POS -
 HOLE DIA -
 DEPTH 273
 CASE-TYP NIL
 CASE-DTH -
 CASE-DIA -
 CASE-THK -

FLUID DATA

FLD TYPE MUD
 FLUIDLEV -
 LOGTYPE TD-5
 APROX SP 6

TOOL: T013--ELOG
 Serial Number: 2158
 Spacer (cm) : n/a

CHANNEL DATA

CHANNEL	AMPLITUDE	RANGE	CHART	AREA	SENSOR OFFSET	FILTER CNST	PLOT TYPE
1 - SPR	153	- 10365	0.0 -	6.0	59	2.0	1
1 - SELF POTENTIAL	-1182	- 1752	6.0 -	12.0	59	2.0	1

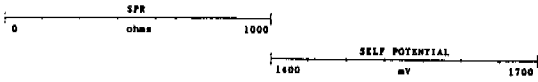
Calibration Data

CHANNEL		slope	offset	C1	C2	C3	C4
1 - SPR	ohms	2.559330	-10618.1	0.000	4149	3300	5438
1 - SELF POTENTIAL	mV	0.872093	-1964.83	0.000	2253	1500	3973

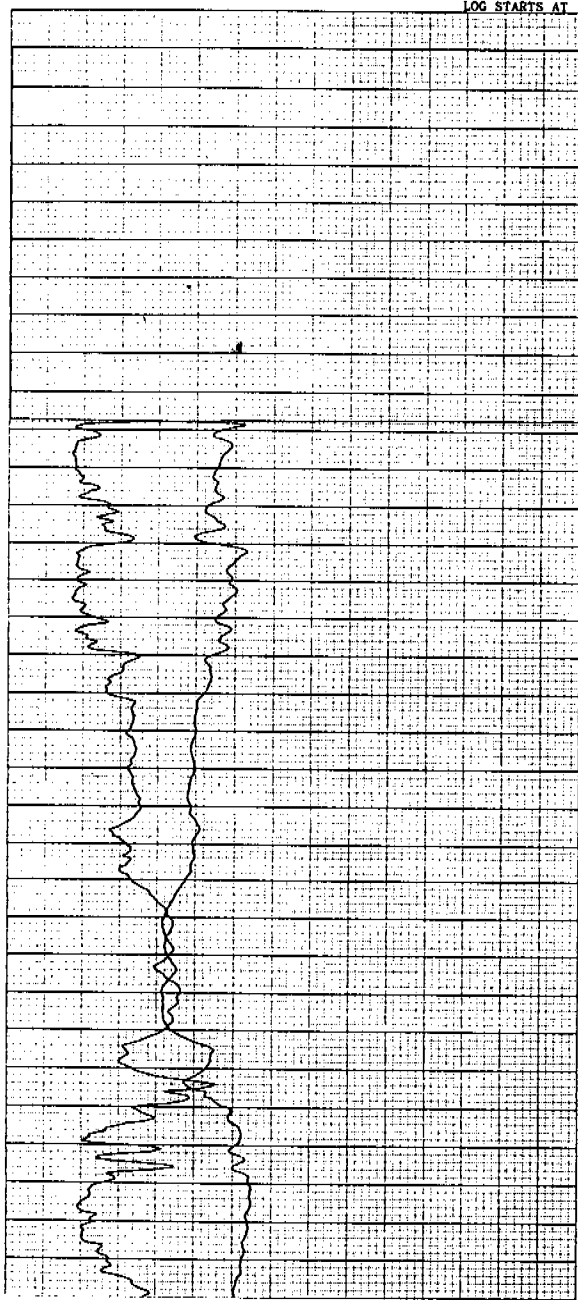
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Logged: UP by DEPTH Interval 5 cm

REPLAY of C:\PI\NTG556-1E at 17:59 on 15/10/96
SCALE: 1 TO 500
without
DEPTH CORRECTION



SELF-POTENTIAL
+
SPR



0.14m.

25

RECENT
 $\frac{\epsilon_{my}}{\epsilon_{mg}}$

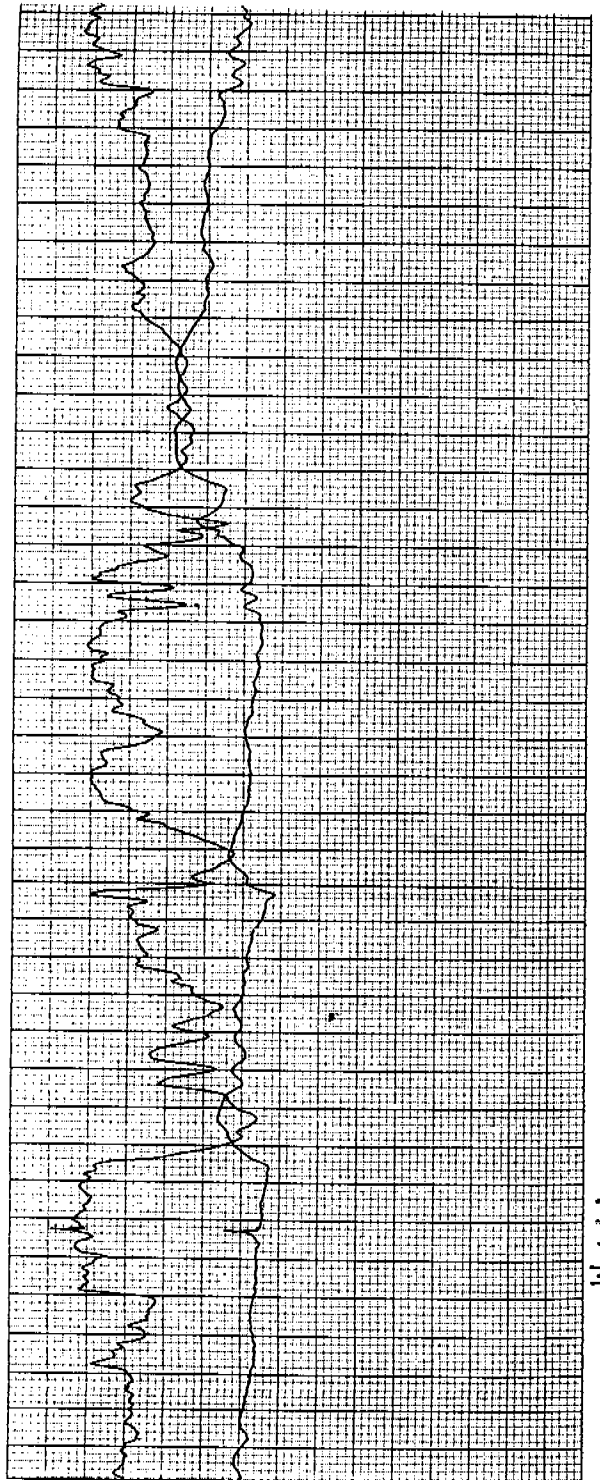
50

$\frac{\epsilon_{my}}{\epsilon_{mg}}$

100

125

150



100

120

150

170

200

220

$\frac{\epsilon_{m^*}}{\epsilon_{lk}}$
 $\frac{\epsilon_{lk}}{\epsilon_{lm}}$
2

230

LOG ENDS AT : 269.09

POWER AND WATER AUTHORITY

HOLE NO: NTGS96/1

LOGGED: 15/10/96 at 16:00

COMPANY PAWA WRB
 AREA HELEN SPRINGS
 PROSPECT CORE HOLE
 OPERATOR P TURNER

DRILLING DATA

PERM DAT -
 ELEV -
 HOLE POS -
 HOLE DIA -
 DEPTH 273
 CASE-TYP NIL
 CASE-DTH -
 CASE-DIA -
 CASE-THK -

FLUID DATA

FLD TYPE MUD
 FLUIDLEV -
 LOGTYPE TD-5
 APROX SP 6

TOOL: T075--GAMMA
 Serial Number: 1239
 Spacer (cm) : n/a

CHANNEL DATA

CHANNEL	AMPLITUDE	RANGE	CHART	AREA	SENSOR OFFSET	FILTER CNST	PLOT TYPE
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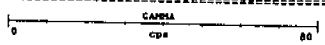
Calibration Data

CHANNEL	slope	offset	C1	C2	C3	C4
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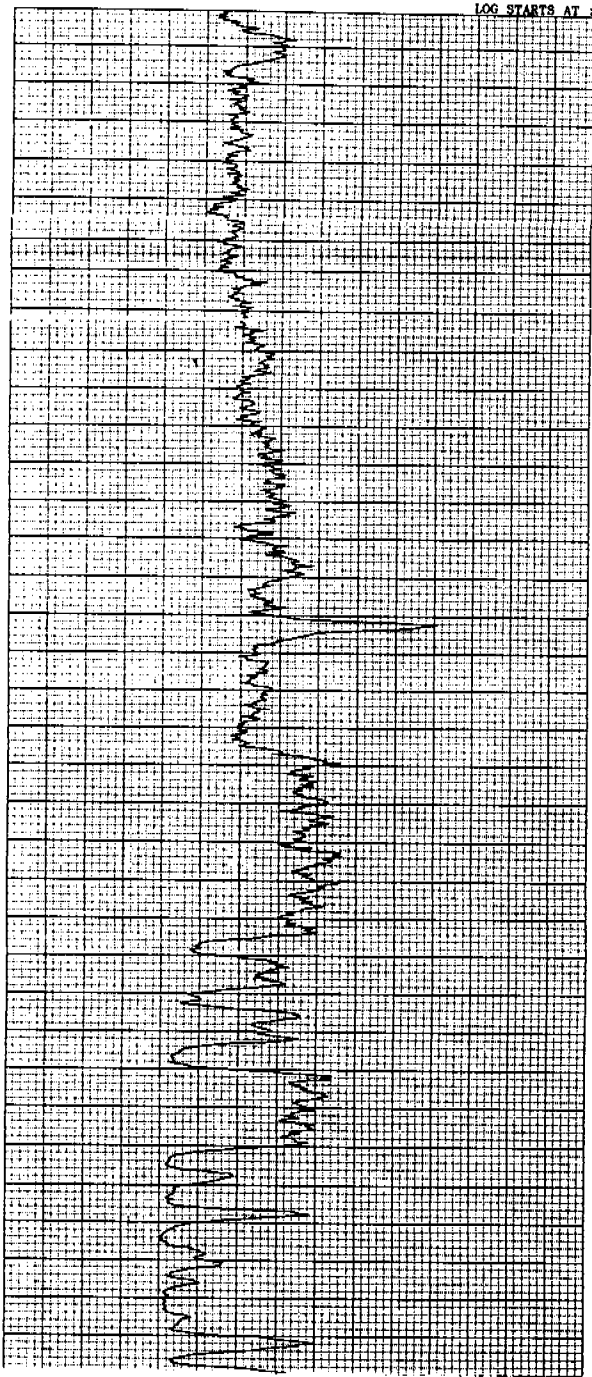
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Logged: UP by DEPTH Interval 5 cm

SCALE: 1 TO 200
without
DEPTH CORRECTION



LOG STARTS AT :



0.15m.

10

20

30

Recent
Emy

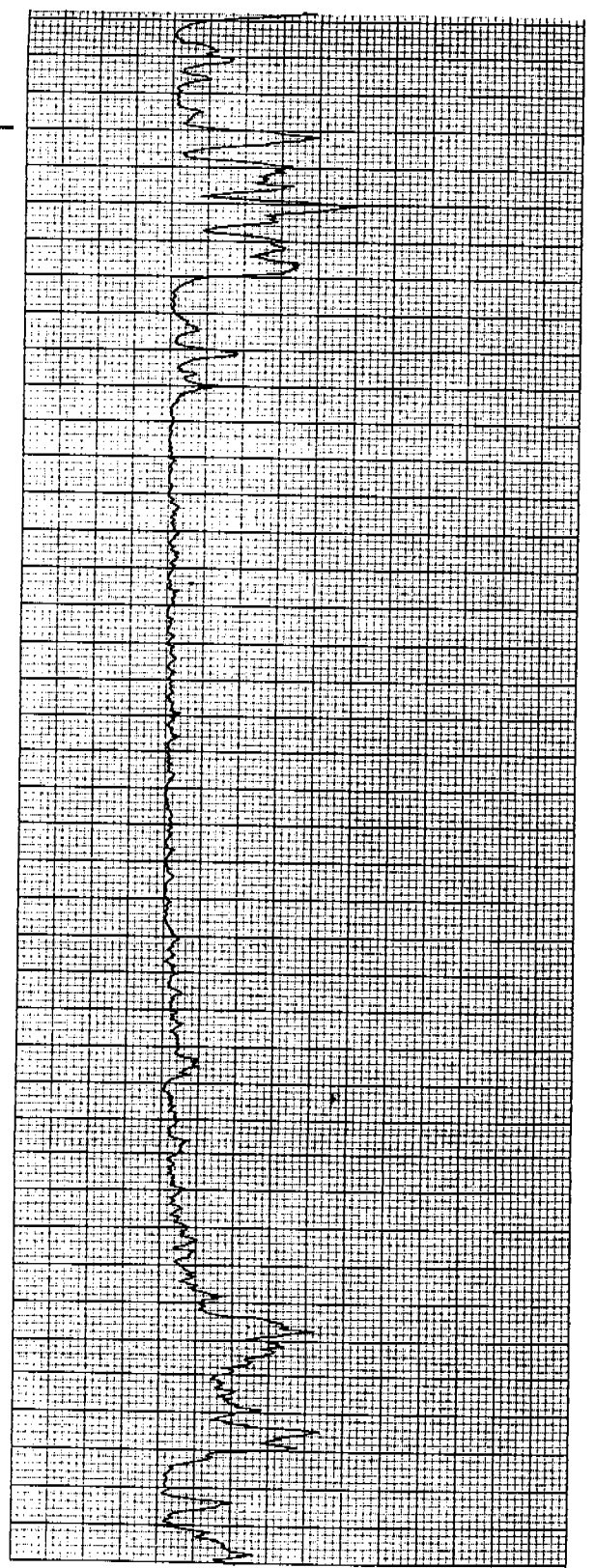
40

50

60

70

GAMMA 1



7

80

$\frac{E}{E_0}$

90

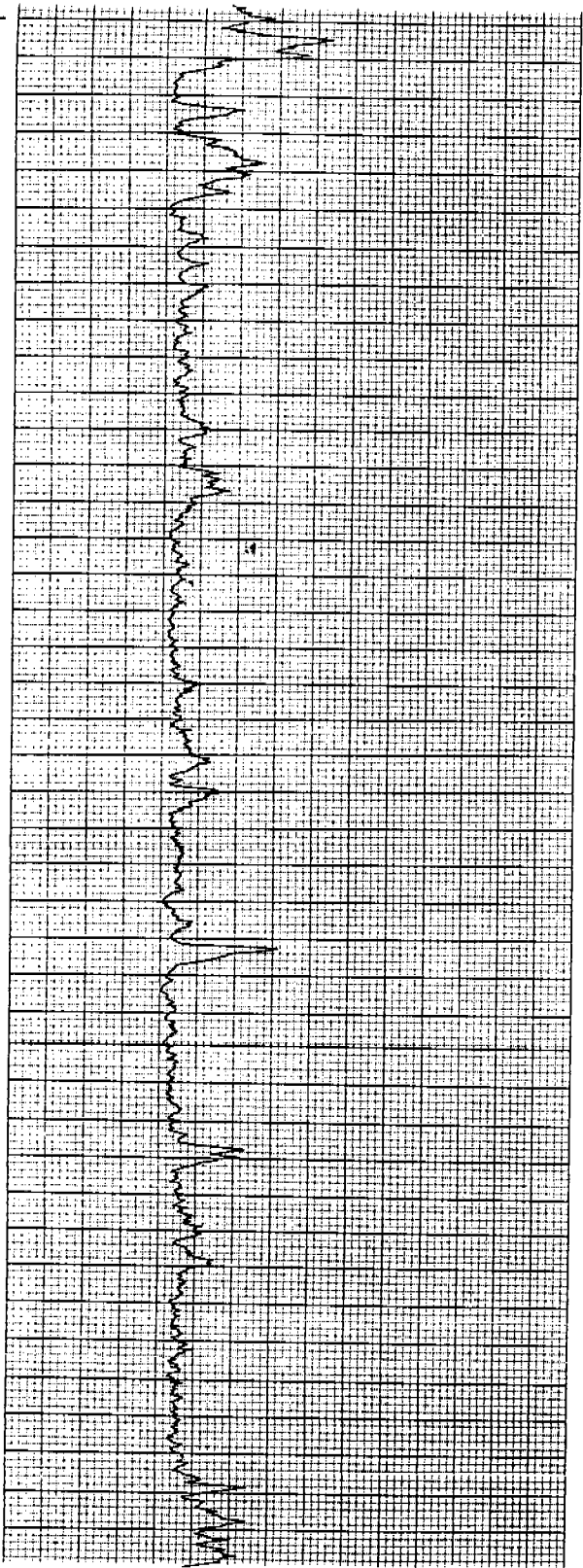
100

110

120

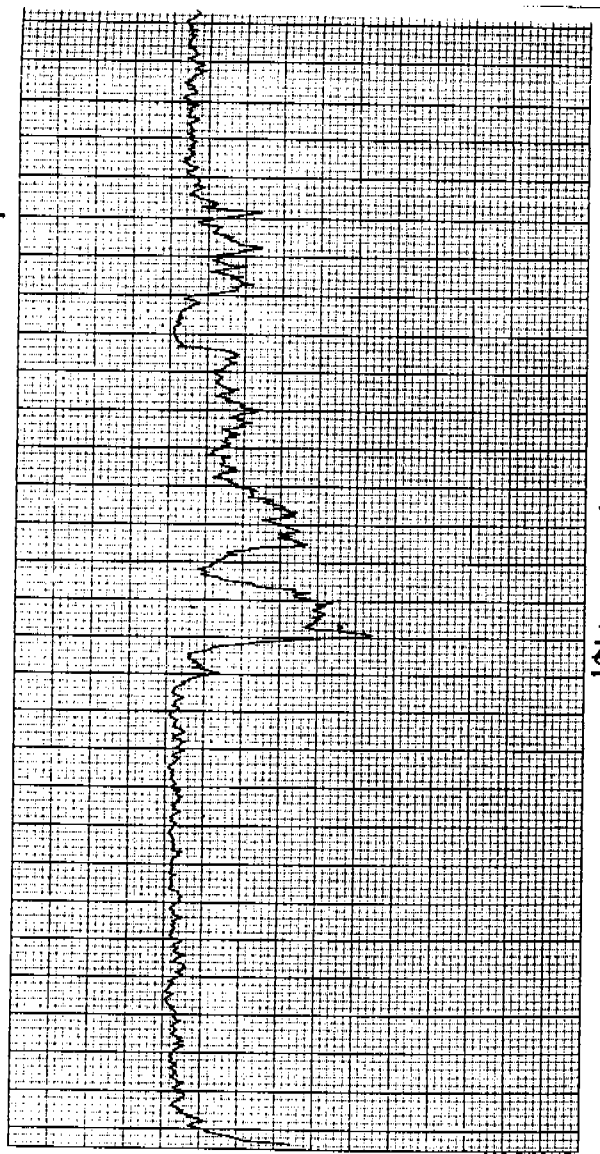
130

140



140
150
160
170
180
190
200
210
220

GAMMA 2



220
230
240
250
260

$\frac{Emg}{Elh}$
 $\frac{240}{Elh}$
 $\frac{Elhm}{l}$

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
HOLE N° NTGS 96/L CO-ORDINATES MY 214640 R.L. GROUND ~ 225 m
LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 20° DIRECTION V

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES
	NO CORE		
Red clay			HQ ↓
White clay			
Red clay with admixed quartz silt and sand		95-100%	

0

10

20

REFERENCES	LOGGED BY <u>PD KRUSE</u>
	SHEET <u>1</u> OF <u>14</u> DRAWING N°






GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NTGE 96/1 CO-ORDINATES MV 214 640 R.L. GROUND ~220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

20

30

40

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES
<p>Red clay with admixed quartz silt and sand</p>		<p>95-100% 65% 95-100% 50% 95-100% 0% 95-100% 0%</p>	
<p>White-yellow clay</p>		<p>95-100%</p>	<p>Recent 34.1m</p>
<p>Grey mudstone</p>			<p>Emy</p>
<p>Maroon siltstone, micaceous, with nodular to quasibedded arenite and grey dolomudstone; mottled.</p>		<p>100%</p>	

Thickness Recent = 34.1m

REFERENCES

LOGGED BY

PDK

SHEET 2 OF 14

DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NTGS 96/1 CO-ORDINATES MV 24640 R.L. GROUND ~ 220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

40

DESCRIPTION OF CORE

LOG

CORE RECOVERY %

SAMPLES

Maroon siltstone, micaceous, mottled, with nodular to quasi-bedded evaporite and grey dolomudstone

50

Cream claystone

100%

Yellow-grey cryptomicrobial laminite

Maroon siltstone with common disrupted and truncated bedding in maroon-brown fine interbeds

Cream claystone

Yellow-grey dolostone with porosity possibly after evaporites; cryptomicrobial at top and base

Grey mudstone

Grey microbial dololaminite

Yellow-grey mudstone

Maroon siltstone, mottled and brecciated

Yellow-grey cryptomicrobial dololaminite with bedding-selective porosity

Mottled maroon-olive green-grey siltstone with scattered evaporite

Yellow-brown cryptomicrobial dololaminite

Maroon siltstone, mottled, with nodular to quasi-bedded evaporite



TS 59.4m

Breccias at 54.2, 54.3, 54.8m: brown mudstone, tabular pebble-size clasts in maroon siltstone

60

REFERENCES

LOGGED BY

PDK

SHEET 3 OF 14

DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE NO. NTGS 98/1 CO-ORDINATES NV 214 640 R.L. GROUND ~ 220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

60

70

30

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES
Maroon siltstone as above			▲
Yellow-brown dolostone, partially laminated, with possible fenestral toward base; cryptomicrobial dololaminite at base			≡
Grey mudstone with scattered granule- to small pebble-size subangular-angular clasts			≡
Yellow-brown fenestral dolostone; becomes thin-bedded, stylolitic and cryptomicrobial toward base			TS 62.8m
Grey mudstone with scattered granule- to small pebble-size subangular-angular clasts			≡
Yellow-brown-grey cryptomicrobial dololaminite with fine porosity			≡
Yellow-brown massive, fenestral dolostone with cm-scale coarse porosity			≡
Grey mudstone			
Yellow-brown-grey dolostone, partially porous, partially thin-bedded to laminated and stylolitic			≡
Yellow-brown-grey cryptomicrobial dololaminite including domal stromatolites			≡ domal stromatolites
Yellow-brown dolostone with dark grey silticlastic thin laminations; becoming fenestral (some with cement-occluded porosity) toward base			
Grey, thin-bedded to laminated dark/light dolostone with common stylolites; cryptomicrobial at base		100%	≡
Grey mudstone with nodular evaporites			▼
Maroon siltstone with nodular evaporites			▼
Brown-grey cryptomicrobial dololaminite; stromatolites at 71.9m			≡ linked stromatolites TS 71.9m
Maroon siltstone with scattered evaporites and brown dolomitic mudstone flat/tabular pebbles			?▼
Yellow-brown dolostone with fenestral			▼
Grey mudstone with nodular evaporite			▼
Maroon siltstone, mottled, with flat pebbles of light grey dolomudstone at 75.5-75.6m			▼
Yellow-brown dolostone with thin (mm-scale) interbeds of olive green silticlastic mudstone			TS 75.9m
Maroon (and minor grey) mottled siltstone			
Grey mudstone, mottled			
Yellow-grey dolostone with bedding-selective fine porosity			

REFERENCES

LOGGED BY EDK

SHEET 4 OF 14

DRAWING NO

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NTGS 86/L CO-ORDINATES MY 214640 R.L. GROUND 220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

80

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES
Yellow-grey dolostone with bedding-selective fine porosity; cryptomicrobial at 80.2 and 80.7 m			≈
Grey mudstone, mottled			≈
Yellow-brown cryptomicrobial dololaminite, flat-laminated		100%	≈ [TS] 81.7 m
Yellow-brown dolomitic mudstone			≈
Grey mudstone with scattered and clustered nodular evaporites			▼ [TS] 82.7 m
Yellow-brown dolomitic mudstone with nodular and bedding-parallel siliceous concretions			≈ [P] 83.7-83.9 m
Grey and yellow-grey dolostone; cryptomicrobial at 83.6 m			≈ Emy 84.4 m
Yellow-brown dolomitic mudstone with dark grey siliciclastic laminations toward top			≈ [P] Emg 84.6-84.8 m
Mid-grey limestone, cm-scale nodular, stylolitic, stromatolitic			[P] 85.5-85.7 m
Light yellow-grey, partially dolomitised limestone, mottled, with bedding-selective secondary porosity			[P] 86.9-87.1 m
			[P] 90.9-91.1 m
		100%	[P] 92.5-92.7 m
Light grey limestone, mottled, with common dark grey siliciclastic laminations defining cm-scale nodular texture; secondary patchy dolomitisation superimposed; intervals of coarse and fine porosity			[TS] 94.6 m

Thickness Emy = 50.3m⁺

90

100


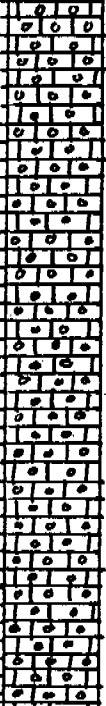
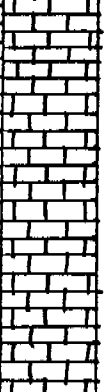
REFERENCES

LOGGED BY PDK
 SHEET 5 OF 14 DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NIES 26/L CO-ORDINATES MV 214640 RL GROUND ~ 22.0 m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

100

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES
<p>Light grey limestone as above</p>			<p>[P] 100.8-101.0 m</p> <p>[P] 106.8-107.0 m</p>
<p>Light grey, mottled to massive, partially dolomitised limestone with a few dark grey siliciclastic laminations; patchy dolomitisation; intervals of coarse and fine porosity; ?sponges at 113.5-114.4 m</p>		<p>100%</p>	<p>[TS] 113.6 m</p> <p>⊙ ⊙</p>
<p>Light grey limestone, mottled, with common dark grey siliciclastic laminations defining cm-scale nodular texture; patchy secondary dolomitisation superimposed; intervals of coarse and fine porosity; ?burrows</p>			<p>[P] 116.6-116.8 m</p>

20

REFERENCES

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SHEET 6 OF 14

DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NTGS 96/1 CO-ORDINATES MV 214640 R.L. GROUND ~ 220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

120

DESCRIPTION OF CORE

LOG

CORE RECOVERY %

SAMPLES

*Light grey limestone as above;
 ?sponges at 125.2m*

P 124.0-124.2 m

⊙ TS 125.2 m

130

100%

P 134.7-134.9 m

⊙

P 137.9-138.1 m

TS 139.1 m

P 139.8-140.0 m

140

*Dark/light grey siliciclastic mudstone/
 limestone interbeds ("two-tone"
 limestone); burrows (some with
 geopetal internal sediment), microfossils,
 ?siliceous concretions in limestone
 beds; which tend to be boudinaged;
 interbeds mm- to cm-scale*

REFERENCES

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SHEET 7 OF 14

DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NIGS 26/1 COORDINATES MV 214640 R.L. GROUND ~220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

40

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES	
"Two-tone" limestone as above			↑ HQ P 140.9-141.2m NQ ↓	
Light grey limestone with thin dark grey siliciclastic laminations; burrows/fossils				
Mid-grey limestone - calcimudstone with dark grey siliciclastic laminations				
Grey onkoid limestone			TS 143.0m	
Mid-grey limestone - calcimudstone with dark grey siliciclastic laminations				
Yellow-grey calcimicrobial dololaminite; stromatolites at 143.0 m				
Yellow-grey limestone - dolomitic calcimudstone with dark grey siliciclastic laminations				
Mid-grey limestone - calcimudstone with dark grey siliciclastic laminations				
Yellow-grey limestone - dolomitic calcimudstone with dark grey siliciclastic laminations				
Grey mudstone, mottled; calcimicrobial dololaminite at 149.1m				
50	Yellow-grey dolostone and subordinate grey dolomitic limestone with dark brown and dark grey (respectively) siliciclastic laminations; evaporites at 149.7 and 151.6m; visible sulphides at 150.7m; dololaminite at 151.3m		100%	P 150.3-150.6m TS 151.5m
Grey mudstone, mottled				
Yellow-grey dolostone and grey dolomitic limestone with dark siliciclastic laminations; calcimicrobial dololaminite at 152.8-153.0m			P 153.1-153.4m	
Massive grey, vaguely laminated, stylonitic limestone with light brown-grey cm-scale bedding-parallel and nodular intervals of dolomitisation and of dolomitic (and partially silicified) concretions			P 159.3-159.6m	

50

REFERENCES

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DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NTGS 96/1 CO-ORDINATES MV 214640 R.L. GROUND ~220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

160

DESCRIPTION OF CORE

LOG

CORE RECOVERY %

SAMPLES

Massive grey limestone as above

TS 164.9 m

170

Light grey limestone of coalesced
?onkoids / ?concretions with minor
internodular dolomitic limestone;
some stylolites

TS 168.7 m
P 168.7-169.0 m

100%

Massive grey, vaguely laminated,
stylolitic limestone with light
brown-grey cm-scale bedding-
parallel and nodular intervals
of dolomitisation and of dolomitic
(and partially silicified) concretions

180

Gray limestone as below

REFERENCES

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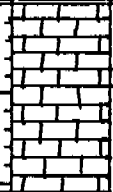
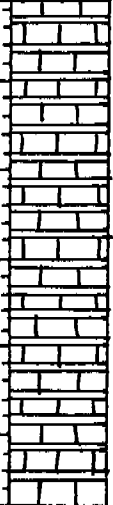
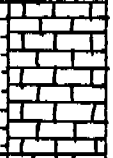
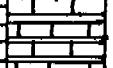
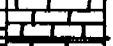
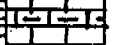



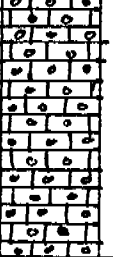
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DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NIGS 9671 CO-ORDINATES MY 214640 R.L. GROUND 220 m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

80

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES
<p>Grey limestone with nodular to well bedded interbeds of dark grey, more siliciclastic sediment; stylolites</p>			<p>[P] 180.2-180.5m</p>
<p>Dark/light grey dolomitised siliciclastic mudstone/limestone interbeds ("two-tone" limestone); hypolites and other microfossils visible throughout; some ?siliceous concretions in limestone beds, which tend to be boudinaged toward top, but thicker (cm-scale) elsewhere</p>			<p>⊙ [TS] 182.7 m</p> <p>[P] 183.1-183.4m</p> <p>⊙ [P] 187.5-187.8m</p>
<p>Light grey limestone with nodular to well bedded interbeds of darker grey, more siliciclastic sediment; stylolites</p>			
<p>Dark/light grey siliciclastic mudstone/limestone interbeds ("two-tone" limestone)</p>		100%	<p>⊙</p>
<p>Light grey bioclastic limestone</p>			<p>⊙ [P] 190.4-190.7m</p>
<p>Dark/light grey "two-tone" limestone</p>			
<p>Yellow-grey partially dolomitised marly limestone with patchy fine porosity</p>			
<p>Grey, partially dolomitised limestone, vaguely laminated, with some dark grey siliciclastic laminations and concretions</p>			
<p>Grey mottled limestone with scattered onkoids bearing bioclast nuclei; partially dolomitised</p>			<p>⊙ [TS] 196.6 m</p>
<p>Dark/light grey mottled, nodular, partially dolomitised limestone with dark grey siliciclastic laminations</p>			

90

100

REFERENCES

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SHEET 10 OF 14

DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NTGS 26/1 CO-ORDINATES MV 214 640 R.L. GROUND ~ 220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

200

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES
Dark/light grey limestone as above			P 201.2-201.5m
Dark/light grey siliclastic mudstone/ limestone interbeds ("two-tone" limestone)			⊙
Light grey/yellow-brown limestone "Two-tone" limestone			⊙
210 Light grey/yellow-brown limestone, partially dolomitised (→ yellow-brown), coarsely mottled to nodular, with abundant stylolites, scattered microfossils		100%	P 214.5-214.8m TS 215.7m
220			⊙

REFERENCES

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DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NTGS 26/L CO-ORDINATES MY 214640 R.L. GROUND ~ 220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 90° DIRECTION V

220

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES
Light grey/yellow-brown limestone as above			 [P] 221.2-221.5m
Dark/light grey interbeds of thin-bedded to laminated siliciclastic mudstone and limestone			
Light grey/yellow brown limestone "Two-tone" limestone			[P] 223.5-223.8m
Light grey limestone, nodular to mottled, partially dolomitised, with dark grey siliciclastic laminations, stylolites; onkoids at 225 and 226m			[P] 224.0-224.3m
		100%	[TS] 225.0m
		100%	[P] 225.5-225.8m
Grey marly limestone, partially dolomitised, with mottled to disrupted and brecciated laminations		100%	[P] 226.7-227.0m
Grey to yellow-grey to salmon pink-brown marly limestone, partially dolomitised, brecciated (with rounded to angular clasts up to 4cm size in darker grey marl matrix)			[P] 228.1-228.4m
		100%	[TS] 230.4m
Maroon, mottled and finely brecciated siltstone			[TS] 230.4m Emg 234.9m Elh
Dark green-grey basalt; becomes brownish toward base; amygdaloidal intervals at 239.6-242.2m and 234.9-236.7m		100%	[TS] 239.4m Thickness Elh = 7.3m
		100%	

230

240

Thickness Emg = 150.5m

Thickness Elh = 7.3m

REFERENCES

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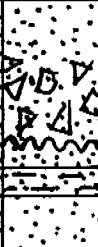



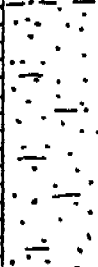
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DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE N° NTS 96/1 CO-ORDINATES MV 214640 R.L. GROUND ~220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 20° DIRECTION V

240

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES
Dark green-grey basalt as above		100%	[TS] 241.2 m Elh 242.2 m
Brown porous, cross-bedded quartz sandstone, passing downward into basal breccia of angular R sandstone cobbles in same sandstone matrix as above		100%	[TS] 243.6 m Elhm 243.8 m Thickness Elhm = 1.6 m
Pale brown quartz sandstone, well sorted			R
Red-brown quartz sandstone with clay + Fe-oxide matrix			
Pale yellow-grey-brown quartz sandstone, locally cross-bedded; breccia of sandstone in reddened quartz matrix at 253.2 m		100%	[TS] 249.2 m
Pale yellow-grey brown quartz sandstone; locally discoloured to purple as below			

250

260

REFERENCES

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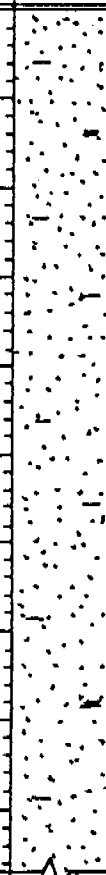

DRAWING N°

GEOLOGICAL LOG OF DRILL HOLE

PROJECT HELEN SPRINGS REMARKS GEORGINA BASIN
 HOLE No NTGS 96/1 COORDINATES MV 214640 R.L. GROUND ~ 220m
 LOCATION NILLY WATERHOLE ANGLE FROM HORIZONTAL 20° DIRECTION V

260

170

DESCRIPTION OF CORE	LOG	CORE RECOVERY %	SAMPLES
<p>Pale yellow-gray-brown quartz sandstone as above; locally discoloured to purple, both constrained by and cross-cutting bedding, by admixed purple mud, which locally forms discrete mm-scale beds</p>		<p>100%</p>	<p>TS 263.2m</p> <p style="text-align: right;">↑ NQ 269.7m</p> <p style="writing-mode: vertical-rl; transform: rotate(180deg);">Thickness P = 25.9m +</p>
<p><u>KEY:</u></p>	<p>TD</p> 		<ul style="list-style-type: none"> ◇ sulphide mineral ⊙ invertebrate fossil ▼ evaporite ≡ cryptomicrobial, stromatolite ⋈ flat, pebble breccia or conglomerate — concretion ⊙ onkoid △△△ breccia, conglomerate ••• amygdaloides (Flh only) <p>TS thin section P palaeontological acid sample</p>

REFERENCES

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