DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
FOSSIL FUELS DIVISION

BUMBARLOW 1 - WELL COMPLETION REPORT

by

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PETROLEUM SECTION

Rept.Bk.No.78/117
G.S. No. 6083
DM. No. 572/77

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DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

Rept.Bk.No. 78/118
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BUMBARLOW 1 - WELL COMPLETION REPORT

ABSTRACT

Bumbarlow 1, situated near the northeastern shores of Lake Frome, continuously cored over 300 m of flat-lying Proterozoic sediments with interbedded lavas. This sequence was intersected below 209 m of Mesozoic strata of the Great Artesian Basin and 192 m of Tertiary to Recent sediments. Rb-Sr whole rock dating upon shales interbedded within a sequence of lavas suggests an age of 1360 $\pm$ 140 Ma for the Proterozoic section on the Benagerie Ridge.

Results from Bumbarlow 1 have reduced the area of presumed Cambro-Ordovician strata within the eastern Arrowie Basin, but have not reduced the petroleum potential of the Cambro-Ordovician sediments expected to exist over most of the area north and northeast of Lake Frome.

INTRODUCTION

Bumbarlow 1 is a stratigraphic well drilled by the Fossil Fuels Division during April to June 1978. It was designed to test the lithologies and petroleum potential of the Cambrian section in the central parts of the eastern Arrowie Basin (Fig. 1). This report presents the technical details and results of the drilling programme and also introduces new concepts regarding the eastern Arrowie Basin.

WELL HISTORY

BUMBARLOW 1

GENERAL

Well Name

South Australian Department of Mines and Energy

Bumbarlow 1

Location

Latitude : 30° 29' 50" S
Longitude : 140° 05' 15" E

Map References

1: 250 000 FROME SH 54-10
1: 100 000 Pundalpa

S.A. Department of Mines and Energy Unit Number

6937000 SW 00010

Petroleum Tenement

PEL's 5 and 6 (Delhi International Oil Corporation and Santos Ltd.)

Elevation

Rotary Table : 850 mm above ground level (all depths are from g.l.)

Ground Level : 31.146 m a.s.l.

Total Depth

720.33 m (driller)

Drilling Commenced

13: 45 hours, 4th April 1978

Drilling Completed

12: 30 hours, 13th June 1978

Actual Drilling Time

43 days (1 shift per day)

Well Completed

15th June 1978

Rig Released

15th June 1978

Status

Dry and abandoned

DRILLING DATA

Drilling Contractor

S.A. Department of Mines and Energy
Mechanical and Drilling Branch
Dalgleish Street
Thebarton, S.A. 5031.

Drilling Rig

Failing 1500 (R.D. 3)

Hole Sizes

5½ ins. to 410.00 m
NQ core from 408.95 to 720.33 m

Casing and Cementing Details

6" casing 18.54 m to Sfce.
3" casing 410.00 m to Sfce.
3 sacks cement at 45 m
5 sacks cement at 380 m

Bit Record

Tricone rollers: 3 used
Hawthorn blades: 3 used
Diamond & Boast NQ diamond: 8 used
Mindrill NQ diamond: 2 used

Water Supply

Drilling and non-drinking camp water supplies were obtained from Cootabarlow 3 bore (see Fig. 1 for location).

Formation Sampling

Ditch Cuttings were taken at 3 m intervals from surface to 410 m.
Cores were cut continuously between 408.95 and 720.33 m; averaged recovery was 97.3%.
The only core loss was between 457.50 and 466.00 m.
All cores and a set of washed cuttings are stored at the Glenside Core Library of the South Australian Department of Mines and Energy.

LOGGING

Logging was carried out by the Department of Mines and Energy's 3000-foot logging unit. The following logs were run -

Gamma Ray	0 - 724 m
Neutron	0 - 724 m
Density	400 - 724 m
S.P.	400 - 724 m
P.R.	400 - 724 m
Temperature	400 - 724 m

Resistivity and Caliper logs were not run, owing to an obstruction in the hole at 430 m.

PREVIOUS EXPLORATION

Bumbarlow 1 is the first well to be drilled into the Arrowie Basin since S.A.D.M. Yalkalpo 2 was completed in March 1976. A synthesis of petroleum exploration in the

Arrowie Basin up to 1976 was presented in the well completion report for Mudguard 1 and Yalkalpo 2 (Youngs, 1977; see also Youngs, 1978a).

REASONS FOR DRILLING

One of the recommendations to come out of the Mudguard-Yalkalpo programme of 1975-1976 was that future petroleum exploration within the prospective Arrowie Basin should concentrate on the northern parts of the basin where deeper and more complete sequences of Cambro-Ordovician strata may exist (Youngs, 1977; p. 25-26). Possible locations of the proposed Bumbarlow 1 had to be chosen with both this recommendation and the limited drilling capacity (about 800 m) of the Department's rigs in mind. Bumbarlow 1 therefore was sited at shotpoint 151 on the line CFK (Crusader, 1971) to control possible re-interpretation of seismic data in the area, at a point where the top of the Cambrian was anticipated approximately 380 m below surface and approximately 420 m of Cambro-Ordovician sediments could thus be cored (See Fig. 2 for location and Fig. 3 for seismic section of part of line CFK). Figure 4 shows the depths to magnetic basement and Bouguer Gravity anomalies in the area. The well was located 16 km southwest of Cootabarlow 3 which provided good supplies of drilling and camp water (see Ker, 1966, for details).

It was anticipated that Bumbarlow 1 would drill 150 m of Tertiary-Quaternary sands and clays overlying 230 m of Mesozoic clays and claystones. The underlying Arrowie Basin section was anticipated to be Middle to Late Cambrian in age and to comprise sediments similar to those of the Lake Frome

Group and Wirrealpa Limestone of the Flinders Ranges.

RESULTS OF DRILLING

The post-Palaeozoic section in Bumbarlow 1 was slightly thicker than anticipated. The base of the Tertiary was at 192 m and the base of the Mesozoic occurred at approximately 401.50 m (21.50 m deeper than prognosis). Lithologies were as expected - predominantly sticky grey clays, with some sands at the top of the section and in the Eyre Formation (160-192 m) (see Composite Log, Figure 7, and Appendix 1). A little over 7 metres of conglomerate was intersected at the base of the Mesozoic.

The expected pre-Mesozoic sequence was entered at 401.50 m and a conformable sequence of red and green conglomerates, sandstones and siltstone with interbedded volcanics was intersected down to a depth of 702.25 m. A sequence of dark grey-black shales from 702.25 m to the total depth of 720.33 m may be disconformable with the overlying beds. Core descriptions of these sediments and lavas are presented in Appendix 2 and the results of detailed thin section petrography are presented in Appendix 3.

In summary, the section from 401.50 m to 702.25 m is a sequence of flat-bedded clastics, in which red and brown sandstones and conglomerates predominate, and wherein seven separate basalt and dacite flows occur between the depths of 509.40 m and 675.75 m. Green-grey sandstones and mudstones also occur in the sequence but mudstones are present in beds generally thinner than those of the coarser lithologies. Some crossbedding and rare flaser bedding occur.

The lavas range from 4.5 to 33.0 metres in thickness. They are mainly finegrained but several of the flows exhibit vesicular and brecciated textures at the top. The bases are

all clearly discernible but only one flow (the lowermost, 669 m to 673.50 m) has a "baked" zone a few centimetres thick below its base.

The dark grey-black shales below 702.25 m constitute a very different facies from the overlying conglomerates and sandstones, with which they are probably disconformable. These shales are finely bedded, dolomitic, and in some places exhibit a possible cleavage (see Appendix 2).

Initial investigations have revealed no fossils in the pre-Mesozoic section and it seems unlikely that any, except perhaps trace fossils, would be found in these generally coarse sediments.

Shale samples from beds at approximately 645 m have been dated by the Rb-Sr whole rock method at AMDEL (Appendix 4) and results suggest an age of 1360 $\pm$ 140 Ma.

INTERPRETATION OF RESULTS

(i) Stratigraphy

The sediments and lavas below 401.50 m in Bumbarlow 1 are considered to be entirely Proterozoic.

The isotopic age of 1360 $\pm$ 140 Ma for shales at 645 m correlates reasonably well with ages of 1160 to 1350 Ma for the rhyolite in Mudguard 1 (Appendix 4 this report and Appendix 4 in Youngs, 1977). This age in Bumbarlow 1 is interpreted as representing the age of deposition of the sediments and lavas. The possibly disconformable black shales at the base of the hole are older than the "red beds" above, but are not interpreted as being significantly older and most probably are not Carpentarian.

The Mesozoic and younger sediments drilled in Bumbarlow 1 were lithologically as predicted and are interpreted as having been deposited in terrestrial to marine environments during

the Mesozoic and terrestrial environments during the Tertiary and Quaternary (Wopfner, 1969; Callen, 1976).

The red and green sediments between 401.50 and 702.25 m are interpreted as fluvial and represent deposition in fluvial fan and upper flood plain environments. The basic to intermediate lavas were extruded from a nearby volcanic province, the location of which is currently unknown.

The grey-black shales might be interpreted as having been deposited in the deeper parts of a lake - the fine, rhythmic bedding of these silty shales is characteristic of lacustrine deposition. A quiet marine environment is also a possibility.

(ii) Structure

The Proterozoic section in Bumbarlow 1 contrasts markedly with the Cambrian sections penetrated in wells to the southwest (Lake Frome 1, 2 and 3: Delhi Australian Petroleum, 1968), where gently folded strata can be correlated with rock sequences in the Flinders Ranges. A sequence reasonably similar to those in the ranges also was intersected in Yalkalpo 2 to the southeast (Figs. 1 and 5) (Youngs, 1977 & 1978a). Regional studies suggest that Cambrian sedimentation extended across the Benagerie Ridge and its Proterozoic sedimentary cover, and that post-Cambrian earth movements, possibly associated with the Delamerian Orogeny (Fig. 5), resulted in erosion of the Cambrian cover. The earth movements may have occurred by faulting along the western and eastern margins of the horst-like ridge: a north-south line of mound springs near the eastern shores of Lake Frome may be related to faulting at depth (Callen, 1976) (Fig. 1), and other faults are thought to occur along the eastern ridge margin (Youngs 1977, 1978a).

This concept of a meridionally faulted western margin to the Benagerie Ridge also is supported by results from seismic surveys, whereby Crusader (1971) identified several north-south faults and gentle folds in the Lake Frome area.

The absence of Cambrian strata in Bumbarlow 1 shows that the Benagerie Ridge and its cover of Proterozoic sediments and lavas extend farther north than was previously suspected (Youngs, 1978a, fig. 2); its northern limit remains undefined at present (Fig. 1).

GEOLOGICAL HISTORY

This brief summary of the interpreted geological history of the Bumbarlow area incorporates data from wells within the region and the earlier work of Callen (1976, 1977) and Youngs (1977). Figure 5 summarizes stratigraphic relationships and tectonic events in four wells in the Benagerie Ridge area.

1. Deposition of dark muds in a possibly lacustrine environment during the post-Carpentarian to pre-Adelaidean period.
2. Relatively short-lived hiatus in which some secondary dolomitization of the shales occurred. Minor tectonism to expose nearby sources of sediments and also possibly to erode uppermost portion of the shale sequence.

3(a) Deposition of coarse sediments in fluvial environments approximately 1360 Ma ago. The metamorphic, igneous and sedimentary sources for these sands and conglomerates were relatively close and minor local earth movements caused episodic rejuvenation.

(b) Contemporaneous volcanism in adjacent areas resulted in the intercalation of seven predominantly basic lava flows with the sandy terrigenous sediments.

4. A period of erosion may have occurred before the onset of metamorphism associated with the Musgravian Orogeny (Fig. 5). This metamorphic event apparently did not cause folding

in the area. There may have been some movement along the north-south faults in the area but the region was basically a very stable one: it has been named the Curnamona Cratonic Nucleus (Thomson, 1976).

5. Deposition of Adelaidean and Cambro-Ordovician sediments most probably occurred across this cratonic nucleus, since results from Lake Frome 1, 2, and 3 (Delhi Australian Petroleum, 1968) and Yalkalpo 2 (Youngs, 1977, 1978, a & b) suggest that Early to Middle Cambrian sedimentation was widespread in the eastern Arrowie Basin.
6. During the Late Cambrian-Ordovician Delamerian Orogeny extensive folding and faulting occurred in the Flinders Ranges and about the Lake Frome area, but these events are not evident within the Curnamona Cratonic Nucleus.
7. Fault movements may have occurred at this time or during the later Palaeozoic, and the Benagerie Ridge horst block was uplifted, leading to erosion of much of the Adelaidean and Cambro-Ordovician cover.
8. Probably no further deposition occurred until the Early Jurassic when epeirogenic movements led to the formation of the Frome Embayment of the Great Artesian Basin. A thin basal conglomerate was deposited in the Bumbarlow area and it was overlain by terrestrial sands and clays. The Early Cretaceous was a time of marine transgression into the Frome Embayment.
9. Terrestrial sedimentation in the Tarkarooloo Basin commenced in the Early Paleocene and has continued sporadically until the present time (Callen, 1976, 1977). Only relatively small earth movements about the horstlike Benagerie Ridge have taken place in this area since the Early Jurassic and sedimentation has been continuous across the horst block.

ARTESIAN WATERS

Bumbarlow 1 was drilled very close to the southern margin of the Frome Embayment of the Great Artesian Basin. Cootabarlow 3 (approximately 16 km to the northeast, see Figure 1) intersected an artesian aquifer at 383 m and water flowed at about 1 million gallons per day (Ker, 1966). It was anticipated that a similar flow might occur in Bumbarlow 1 but no difficulties were encountered and the driller estimated a very small flow of 4 to 6 gallons per hour coming from the basal Jurassic sands.

CONCLUSIONS AND RECOMMENDATIONS

Results from Bumbarlow 1 have significantly reduced the known area of the Arrowie Basin sediments east of the Flinders Ranges. Figure 1 shows the assumed margins of the basin before drilling.

The suggested offlap of Cambrian sediments on the ridge north and west of Mudguard 1 (Youngs, 1977, 1978a) has not been proved and to date only Precambrian sediments and lavas are known to cover the crystalline basement of the Benagerie Ridge. It is possible, however, that Cambro-Ordovician sediments may still drape around the ridge farther to the north (Figure 1).

A suite of previously undiscovered flat-lying Proterozoic sediments and basic lavas was intersected in Bumbarlow 1. It is possible that the rhyolite commonly found in the Mudguard - Black Oak area is at greater depths in Bumbarlow 1 and is deepening northwards (Fig. 6).

Drilling in the eastern Arrowie Basin and on the Benagerie Ridge to date suggests that Cambrian, and possibly also Early Ordovician, strata were deposited throughout the area and the basin may also connect northwards to the Warburton Basin (Figure 1). The Bumbarlow 1 drilling programme has

helped to identify a northerly extension of the Benagerie Ridge and thus has assisted substantially in petroleum exploration. The results of Bumbarlow 1 in no way downgrade the potential of the remaining areas and, in particular, the northern parts of the two lobes on either side of the Benagerie Ridge are still worthy of more exploration.

Recommendations for future exploration in the northern areas of the eastern Arrowie Basin are as follows:-

1. Initial work should be designed to try and determine the boundaries of the Benagerie Ridge in the area north of Bumbarlow 1. Low-cost gravity and magnetic work might be utilized - lines to be located through stratigraphic wells along the ridge and extending into the basinal area.
2. Reprocessing or reshooting of many existing seismic lines (see Figure 2 for location of lines) and also shooting of new lines to help identify the northern margins of the Benagerie Ridge, to determine whether younger sediments might be offlapping in the north and to identify suitable drilling targets.
3. At least two deep stratigraphic wells are recommended:

(i) approximately half way between Bumbarlow 1 and Mt. Arrowsmith in N.S.W. (Fig. 1) - this would test for Cambrian and expected Early Ordovician sediments, which are anticipated have a more marine aspect than strata in the western parts of the basin.

(ii) to be located in the area north of Cootabarlow 1 (Fig. 1) in order to test the possible continuation of sediments into the Warburton Basin.

Any drilling programme undertaken should be designed to investigate fully the source and reservoir potential of the Arrowie

Basin strata and no well should terminate before Precambrian "basement" has been confirmed.

Bridget C. Youngs

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APPENDIX I

Bumbarlow 1

Cuttings Descriptions - Surface to 410 m

by

Bridget C. Youngs

BUMBARLOW 1

Depths are in metres below the ground surface

EURINILLA FORMATION

0-3	Sand, medium brown, fine-medium grained, some coarse, subangular quartz grains.
3-6	a.a.
6-9	Probably a.a. - poor recovery.
9-12	Clay, medium brown (as sands above), silty, some fine - medium quartz grains.
12-15	Probably a.a. - poor recovery
15-18	As for 9-12, possibly more quartz grains
18-21	Clay, medium brown a.a., and subord. Sand. Quartz and gypsum, some 1 mm +.

NAMBA FORMATION

21-24	Clay, red-brown, and medium brown sticky.
24-27	Silt, red-brown and medium brown, tending to be red-brown silt and medium brown clay. Gypsum.
27-30	Clay as for 21-24.
30-33	Clay, medium olive-brown. Sticky.
33-36	Clay a.a. but sl. darker and with yellow-brown and brick-red patches.
36-39	Clay a.a. but darker, ie. dk. brown-grey.
39-42	Clay as for 33-36
42-45	Clay a.a.
45-48	Clay a.a. with large gypsum crystals (20 mm)
48-51	Clay a.a.
51-54	Clay a.a.
54-108	Clay a.a.
108-111	Clay a.a.
111-114	Clay a.a.
114-117	Clay a.a.
117-120	Dolomite, white, chalky

120-123 Clay as for 114-117

123-126 Clay a.a.

126-129 Clay a.a.

129-132 Clay a.a.

132-135 Clay a.a.

135-138 Clay a.a.

138-141 Clay a.a.

141-144 Clay a.a.

144-149 Clay a.a.

147-150 Clay a.a. with grey and red-brown patches

150-153 Clay a.a.

153-156 Clay medium grey, with white patches

156-159 Clay medium grey-brown, lignitic

159-162 Clay a.a.

162-165 Clay medium grey, with white patches, lignitic, and Sand 1-2 mm, qtz.grns, subrd - subangr. Unconsd.

165-168 Sand a.a.

168-171 Sand qtz. grains average ½-1 mm, rare 4-5 mm, subround-subangular. Unconsol.

171-174 Sand a.a. but generally only 1 mm

174-177 Sand a.a.

177-180 Sand brown with white ?dolomite streaks, grains average ¼-½ mm
Unconsol.

180-183 Sand a.a.

183-186 Sand a.a. but grains ½-1 mm

186-189 Sand a.a. but grains upto 3-4 mm

189-192 Sand a.a. but grains ½-1 mm

MARREE FORMATION

192-195 Clay grey-brown, with white patches. Sticky.

195-198 Clay a.a.

198-201 Clay a.a.

201-204 Clay a.a.

204-207 Clay a.a.

207-210 Clay a.a.

10-213 Clay a.a.

213-216 Clay a.a.

216-219 Clay a.a.

219-222 Clay a.a.

222-225 Clay a.a.

225-228 Clay a.a.

228-231 Clay a.a.

231-234 Clay a.a.

234-237 Clay a.a.

237-240 Clay a.a.

240-243 Clay a.a.

243-246 Clay a.a.

246-249 Clay a.a.

249-252 Clay a.a.

252-255 Clay a.a.

255-258 Clay a.a.

258-261 Claystone medium grey, more indurated and less sticky than 192-258.

261-264 Claystone a.a. with subround. quartz pebbles, gypsum plates and rare pyrites.

264-267 Clay grey-brown, sticky.

267-270 Clay a.a.

270-273 Clay a.a.

273-276 Clay a.a.

276-279 Clay a.a.

279-282 Clay a.a.

282-285 Clay a.a.

285-288 Clay a.a.

288-291 Clay a.a.

291-294 Clay a.a.

294-297 Clay a.a.

297-300 Clay a.a.

300-303 Clay a.a.

303-306 Clay a.a. but slightly more indurated

306-309 Clay a.a.

309-312 Clay a.a.

312-315 Clay a.a.

315-318 Clay a.a.

318-321 Clay gr-brn, generally sticky but some more indurated layers.

321-324 Clay a.a.

324-327 Clay a.a.

327-330 Clay a.a.

330-333 Clay a.a.

333-336 Clay a.a.

336-339 Clay a.a.

339-342 Clay a.a.

342-345 Clay a.a.

345-348 Clay a.a.

348-351 Clay a.a.

351-354 Clay a.a.

354-357 Clay a.a.

357-360 Claystone/Shale medium grey

360-363 Claystone/Shale a.a. with rare subround, quartz granules and rare red (? Fe-stone) frags. and rare white sst.

363-366 Claystone medium grey-brown, slightly indurated.

366-369 Clay medium grey-brown with white patches. Sticky.

369-372 Clay a.a.

372-375 Clay a.a.

375-378 Clay a.a.

378-381 Clay a.a. but more indurated in parts

381-384 Clay a.a.

384-387 Claystone/Shale medium grey with quartz pebbles/ granules, red ?Fe-stone frags.

387-390 Claystone/Shale a.a. with increased quartz, ?Fe-stone and sst.

390-393 Claystone/Shale a.a. with increased quartz, ?Fe-stone and sst.

393-396 Claystone/Shale a.a, with increased quartz, ?Fe-stone and sst.

396-399 Conglomerate of yellow, pink, white quartz, minor pink, white sst. Claystone medium grey

399-402 Conglomerate a.a. but with grey and red-pink clays and less gravel than above.

402-405 Clay red-pink and green, sticky. With rare red, green and grey Claystone

405-408 Clay a.a. and Claystone

408-410 Claystone/Shale medium grain and red and rare green, some Clay red and green.

(Continuous coring was commenced at 408.95 m Descriptions of the core recovered from 410 to total depth at 720.33 m are presented in Appendix II).

APPENDIX 2

Bumbarlow 1

Descriptions of Core - 408.95 to 720.33 m

(Dwg. Nos. S13630 a to r)

by

Bridget C. Youngs

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 400 - 420 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
400				
405				Rotary Cuttings' Descriptions Available (Sfce. → 410 m)
408·95				Continuous Wireline Coring Commenced at 408·95 m
		Dip ± 5°		Sandst. grn.-gr., med.-cse., interbedded with Mudst., grn.-gr., rippled. Become maroon downwds. Intrafml. & extrafml. congl. at base.
410				Mudst. grn.-gr. & maroon, laminated & thinly bedded, rippled & burrowed. Congl. bands throughout – rdd. → subrd. grans. of wh.-gr. calc. sst. & red-brn. sltst.
415				Mudst. maroon (rare grn.-gr. streaks & thin beds) with minor Sandst. / Gritst. grn.-gr. (rare maroon) increase in basal 1 m.
420				Sandst., maroon, and Mudst., maroon, with gritst.

CORE BARREL
CORE BIT
TIME—START
FINISH

LOGGED BY B.C. YOUNGS
DATE 11:5:78

PETROLEUM GEOLOGY SECTION

SHEET 1 OF 17 | DRG. NO. S 13630 a

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW. 1 — CORE NO. CONTINUOUS

LOCATION — DEPTH 420 – 440 m

LAT. — DATE DRILLED

LONG. — RECOVERY m %

ELEVATION GR. — DATUM — FORMATION

R.T.

DEPTH (METRES)	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
420				and Congl. bands throughout — clasts = 5→10 mm at top, to 20 mm + at base, subrdd. → rdd., wh.-gr., non-calc. Congl., frags. = few mm. → 400 mm, angr. → subrdd., subparallel to bdg., wh.-gr., maroon, grn.-gr. sst., gritst., mudst. Maroon Sst. mtx. Congl. and Coarse Sandst. a.a. but predom. grn.-gr. with some maroon beds. Basal 600 mm = Rust-brn. & cream frags. (? bsmt.), subangr. → subrdd. in grn. sst. mtx.
425				Congl., angr., gm. sandst. frags (upto 500 mm) in maroon clay matrix. Sandst., Gritst. & Congl. with v. rare Mudst. laams. Cycles of gritst./congl. → sandst. Some gm.-gr. at top but maroon-gr. below 429.80 m. Frags. in congl. = subangr. → subrdd., wh., cream, maroon, few mm → 10 mm, intra— & extrafmt. Rare mudst. frags. Frags. are predominantly metasediments, volcanic & quartz.
430				
435				
440				

CORE BARREL

CORE BIT

TIME—START

FINISH

LOGGED BY B.C. YOUNGS

DATE 11:5:78

PETROLEUM GEOLOGY SECTION

SHEET 2 OF 17

DRG. NO. S 13630 b

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BVM BARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 440 — 460 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	T.S. Nos.	DESCRIPTION
440			As above.
445		P 904/78	
450			
455			N.B. : depths uncertain between 455.91 & 461.73 m. Core lost : ? 457.50 → 466.00 m in Claystone. ? 457.20 → ? 457.50 : Congl. a.a. but coarse sandstone matrix & gravels grade into maroon Mudstone at base. Core lost 457.00 → 466.00 m in Claystone ?/Sandstone.
460			

CORE BARREL
CORE BIT
TIME—START
FINISH

LOGGED BY B.C. YOUNGS
DATE 12:5:78

PETROLEUM GEOLOGY SECTION

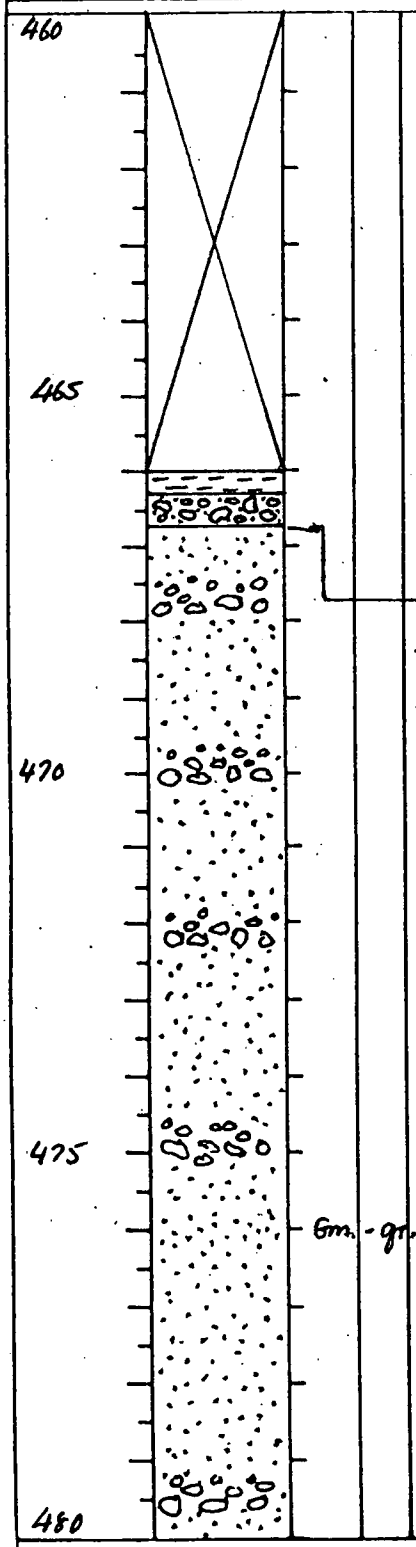
SHEET 9 OF 17 | DRG. NO. S/3630 c

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW . 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 460 – 480 m
DATE DRILLED
RECOVERY m %
FORMATION



DEPTH (METRES)	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
460				Core lost 457.50 → 466.00 m in Clayst.?/Sands.
465				Mudst., maroon, soft. Congl., as for 457.20 m but larger pebbles. Jasper, qutz. etc. pebbles. Loose Sandst. mtx., some red & grn. Mudst. mtx. Maroon Mudst. lamns.
470				Sandst., pink-gr., med.-cse., flat-bdd; Gitst., pink-gr., cse. qutz. frags.; Congl., pink-gr., few clasts > 10 mm, sizes & quantity decrease ↓. Intraful. maroon mudst. clasts & extraful. clasts. Graded beds with channelled bases. Some Congls. show imbrication of clasts. Rare beds of grn.-gr. Sandst. at 476 m & 487 m.
475				
480				

CORE BARREL
CORE BIT
TIME – START
FINISH

LOGGED BY B.C. YOUNGS
DATE 12:5:78

PETROLEUM GEOLOGY SECTION

SHEET 4 OF 17 | DRG. NO. S13630d

DEPARTMENT OF MINES - SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW .1 | CORE NO. CONTINUOUS

LOCATION | DEPTH 480 - 500 m.

LAT. | DATE DRILLED

LONG. | RECOVERY m %

ELEVATION GR. | DATUM | FORMATION

R.T.

DEPTH (METRES)	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
480				As above
				Mudst., maroon, non-lamnd. appears at 483·90 m & increases downwards. Flaser bedding at 489·00 m.
485				
		Grn.-gr.		
490				Mudst., maroon, lamnd.
				Siltst., maroon, to Sandst., maroon, fine-med. With thin maroon Mudst. lamins., & coe. Sandst., grn.-gr., channels.
495				Mudst., maroon, to Siltst., maroon, fine, with rare Sandst. & Congl./Gritst. beds increasing down. Sandst. is coarse grn.-gr.-br. at 489 - 496 m. Becomes conglomeratic in basal 100 mm.
500				

CORE BARREL

CORE BIT

TIME - START

FINISH

LOGGED BY B. C. YOUNGS

DATE 13:5:78

PETROLEUM GEOLOGY SECTION

SHEET 5 OF 17 | DRG. NO. S13630e

DEPARTMENT OF MINES SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 500 - 520 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	T.S. Nos.	DESCRIPTION
500			Gritst. & Congl., maroon, intrafml., mudst. clasts etc. Thin mudst. beds. Channelling.
505		P 905/78	Congl., subrd.–rdd. pebbles, avge. = 10-20 mm, some 50 mm & rarely > 50 mm. Self-supporting pebbles, subparallel to bedding. No apparent grading. Fragments are predominantly quartz or argillaceous sediments / metasediments. Rare ? volcanic pieces.
510		P 906/78	Basic Volcanic Rock; extensively altered and possibly with the introduction of ferruginous material.
515		P 907/78	
520			

CORE BARREL
CORE BIT
TIME – START
FINISH

LOGGED BY B.C. YOUNGS
DATE 18:5:78

PETROLEUM GEOLOGY SECTION

SHEET 6 OF 17 | DRG. NO S13630 f

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 520 - 540 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	T.S. Nos.	DESCRIPTION
520			Siltstone, maroon with rare thin grn. streaks. Rare beds of fine-grained Sst. and some Shale.
525		P 908/78	
530			Mudstone, grn., soapy, crumbly; ? sericite/chlorite. V. thin beds.
535		P 909/78	?Basalt, extensively altered basic volcanic rock. Vesicular. Few xenoliths of argillaceous sandstone. Considerable amount of secondary quartz.
540			

CORE BARREL
CORE BIT
TIME — START
FINISH

LOGGED BY B.C. YOUNGS
DATE 26:6:78

PETROLEUM GEOLOGY SECTION

SHEET 7 OF 17 | DRG. NO. S13630 9

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 540 - 560 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
540				
545				
550				Sandstone, maroon to buff, medium to coarse becoming coarser and conglomeratic downwards. Generally flat bedded, Some mottled patches. Thin beds of grit stone, pink & white, angr. – subangr. grains. Thin maroon mudstone along joints (60° to horiz.).
555				Mudstone, maroon. Rare green mottles. Sandstone, buff – pink brown – maroon, Some x-bedding, with green mudstone defining beds. Rare distorted (? burrowed) beds. Occasional green & green-grey intraformational mudstone clasts. Flasers at 559.50 m.
560				

CORE BARREL
CORE BIT
TIME – START
FINISH

LOGGED BY B.C. YOUNGS
DATE 26:6:78

PETROLEUM GEOLOGY SECTION

SHEET 8 OF 17 DRG. NO. S13630h

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO CONTINUOUS
DEPTH 560 – 580 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	T.S. Nos.	DESCRIPTION
560			a.a.
		P799/78	Basalt – Dacite, highly altered, fine-grained, vesicular at top.
		P910/78	
565			
		P800/78	
570			
575		P801/78	
			Sandstone, brown – cream (rare pl. green siltstone laminations), thinly bedded with some x-beds. Distinct channelled base.
580			

CORE BARREL
CORE BIT
TIME – START
FINISH

LOGGED BY B. C. YOUNGS
DATE 26:6:78

PETROLEUM GEOLOGY SECTION

SHEET 9 OF 17 | DRG. NO. S13630i

DEPARTMENT OF MINES -- SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 580 - 600 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	T. S. Nos.	DESCRIPTION
580			Siltstone, red-brown & green
			Basalt - Dacite, highly altered, vesicular.
585			
		P802/78	
590			
		P911/78	
595			
		P912/78	
600			Sandstone and Gritstone, red-brn., quartzitic, rare muscv. lamins.

CORE BARREL
CORE BIT
TIME - START
FINISH

LOGGED BY B. C. YOUNGS
DATE 26:6:78

PETROLEUM GEOLOGY SECTION

SHEET 10 OF 17 | DRG. NO. S13630 j

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 600 – 620 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	T.S. Nos.	DESCRIPTION
600			a.a.
605			Mudstone, red & green, finely laminated.
			?Basalt, highly altered, generally fine-grained rare vesicles.
610			
615		P803/78	
		P913/78	
620			

CORE BARREL
CORE BIT
TIME – START
FINISH

LOGGED BY B. C. YOUNGS
DATE 26: 6: 78

PETROLEUM GEOLOGY SECTION

SHEET 11 OF 17 | DRG. NO. S 13630 k

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1 — CORE NO CONTINUOUS

LOCATION — DEPTH 620 - 640 m

LAT. — DATE DRILLED

LONG. — RECOVERY m %

ELEVATION GR. R.T. — DATUM — FORMATION

DEPTH (METRES)	GRAPHIC LOG	T.S. Nos.	DESCRIPTION
620			as above.
625			
630		P 914/78	Brecciated basalt – fractures up to 10 mm, filled partly with fine-grained, basaltic debris and quartz + minor calcite.
635		P 804/78	Basaltic andesite
640			

CORE BARREL

CORE BIT

TIME – START

FINISH

LOGGED BY B.C. YOUNGS

DATE 26:6:78

PETROLEUM GEOLOGY SECTION

SHEET 12 OF 17 — DRG. NO. S 13630 L

DEPARTMENT OF MINES - SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 640 - 660 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	T.S. Nos.	DESCRIPTION
640			as above
		P897/78	Mudstone, dk. gr.-grn., predominantly sericite. Narrow bands of siltstone & sandstone. Minor amounts sulphides (pyr. & ? chalcopyr.) along fractures. Micaceous.
		P898/78	
		P899/78	Samples used for Rb.-Sr. dating; 1235 ma. (See Appendix).
		P900/78	
645		P901/78	
		P902/78	
		P903/78	
650		P915/78	Sandstone, felspathic, lithic, coarse-grained, pink. Predominantly quartz — abundant overgrowths & prob. originally sub-rounded grains.
			Basalt
655			
660			

CORE BARREL
CORE BIT
TIME—START
FINISH

LOGGED BY B. C. YOUNGS
DATE 26:6:78

PETROLEUM GEOLOGY SECTION

SHEET 13 OF 17 | DRG. NO. S13630 m

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO CONTINUOUS
DEPTH 660 – 680 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	T.S. Nos.	DESCRIPTION
660			Basalt
665		P 916/78	Siltstone & Mudstone, dark – med. green, pl. – med. grn. sltst. at base. Flat laminations. Dolomitic in parts.
670			Basalt, as above. Baked zone at base, few cms.
675			Sandstone, red & green (red absent below 684 m), med.-cse. grained, quartz, mica & ?red. grains, graded and cross-bedding throughout, rare green siltst. & fine sst. beds throughout. Coarser grnd. to gritst. below 694.75 m, congl. in basal 50 mm. May be disconformity at base.
680			

CORE BARREL
CORE BIT
TIME – START
FINISH

LOGGED BY B.C. YOUNGS
DATE 26:6:78

PETROLEUM GEOLOGY SECTION

SHEET 14 OF 17 | DRG. NO. S13630 n

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 680 - 700 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	T.S. Nos.	DESCRIPTION
680			a.a.
685			
690			
695		P 927/78	
700			

CORE BARREL
CORE BIT
TIME—START
FINISH

LOGGED BY B. C. YOUNGS
DATE 26:6:78

PETROLEUM GEOLOGY SECTION

SHEET 15 OF 17 DRG. NO. S13630 P

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1 — CORE NO. CONTINUOUS

LOCATION — DEPTH 700 - 720 m

LAT. — DATE DRILLED

LONG. — RECOVERY m %

ELEVATION GR. R.T. — DATUM — FORMATION

DEPTH (METRES)	GRAPHIC LOG	T.S. Nos.	DESCRIPTION
700			a.a.
			? disconformity at 702·15 m.
			Shale, dark grey - black with very fine laminations of pale buff. Rare chalcopyrite along bedding planes. ? cleavage = 30° - 40°, in places. Dolomitic in bands.
705			
710		P 918/78	
715			
720			

CORE BARREL

CORE BIT

TIME — START

FINISH

LOGGED BY B.C. YOUNGS

DATE 26:6:78

PETROLEUM GEOLOGY SECTION

SHEET 16 OF 17 — DRG. NO. S13630q

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL BUMBARLOW 1
LOCATION
LAT.
LONG.
ELEVATION GR.
R.T.
DATUM

CORE NO. CONTINUOUS
DEPTH 700 – 720 m
DATE DRILLED
RECOVERY m %
FORMATION

DEPTH (METRES)	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
720	T.D. = 720·33 m			a.a.
725				

CORE BARREL
CORE BIT
TIME – START
FINISH

LOGGED BY B. C. YOUNGS
DATE 26.6.78

PETROLEUM GEOLOGY SECTION

SHEET 17 OF 17 | DRG. NO. S13630 r

APPENDIX 3

Bumbarlow 1

Thin Section Petrography of Selected Core Samples

by

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18 July 1978

6937 RS 38 → 44

Director-General,
Department of Mines & Energy,
Post Office Box 151,
EASTWOOD, 5063.

Attention: Bridget Youngs

REPORT GS 4685/78

YOUR REFERENCE:	Application (undated)
MATERIAL:	7 core samples
LOCALITY:	Bumbarlow No. 1
IDENTIFICATION:	P897/78-P903/78
DATE RECEIVED:	30 June 1978
WORK REQUIRED:	Petrography and suitability for geochronology

Investigation and Report by: Dr Brian Steveson

Manager, Geological Services Division: Dr Keith J. Henley

Keith Henley

for Norton Jackson,
Managing Director.

meo/7

EXAMINATION OF SHALES FROM BUMBARLOW NO. 1

Sample: P897/78; TS40524 6937RS38

Location:
Bumbarlow No. 1, 642.3 m.

Rock Name:
Interbedded shales and siltstones

Thin Section:
The sample consists of several interbedded lithologies and hence it is not possible to give meaningful mineral proportions. The most abundant lithology is a silty shale and this grades towards more siliceous, very fine-grained, argillaceous sandstone and siltstone. In the whole of the rock in the thin section it is unlikely that detrital quartz and feldspars comprise more than about 20% of the rock, although there are individual beds which contain up to about 50% of this material. The remainder of the rock is either micaceous or clay material.

The most quartzitic lithologies are siltstone, which contains quartz fragments up to about 0.04 mm in size. In some ill-defined beds such material comprises possibly as much as 50% of the rock and quartz appears to form a framework. Individual grains are equant but angular in shape and they appear to be reasonably well sorted. In these siltstones and very fine-grained sandstones there is a considerable amount of extremely fine-grained clay, much of which has a moderate birefringence and hence, it is likely to be illitic. Detrital micas are generally confined to no more than about 10-15% of the volume of this part of the rock. As far as can be determined, the intergranular clay is a genuine argillaceous matrix deposited with the quartz grains.

Although it is difficult to give precise details, it appears likely that there is a moderate amount of feldspar in these silty beds. Rare microcline grains are up to 0.07 mm in size and there are partially altered grains which are also interpreted as being feldspars. As far as can be determined, the feldspars have a similar size range to adjacent quartz and they also show considerable diversity of alteration patterns.

In the more micaceous and argillaceous lithologies it is difficult to give textural details since much of the rock consists of a virtually featureless aggregate of fine-grained phyllosilicates. Most of these are more or less brown to a dull green colour in bulk, but there are individual flakes of green biotite and colourless muscovite. These are interpreted as being detrital components and their presence probably precludes successful Rb-Sr geochronology. It is difficult to estimate the overall proportions of these relatively well-defined flakes, but, overall, they may well comprise about 10% of the area of material in thin section. For the most part the biotite is unusually fresh and shows moderate birefringence colours and well-defined pleochroism in shades of green. The bulk of the phyllosilicate material in the rock is "clay" with moderate birefringence colours and this may well be sericitic or illitic material. It generally shows weak or negligible bulk extinction and hence is probably randomly oriented. Within these micaceous parts of the rock there are generally widely dispersed silt-grade quartz grains which are angular and, possibly, partly corroded.

The rock has an essentially laminar foliation on a scale of less than 1 mm.

Sample: P898/78; TS40525 6937 RS 39

Location:
Bumbarlow No. 1, 643.67 m.

Rock Name:
Argillaceous siltstone

Thin Section:
An optical estimate of the constituents gives the following:

	%
Quartz and feldspar	65-80
Mica	10-20
Clay	5-10
Opaques	Trace
Tourmaline	Trace

As the mineral proportions indicate, this is a relatively quartz-rich, fine-grained sediment and the proportion of detrital quartz and feldspar varies in different parts of the thin section from about 65% to 80%. Mica has been used to indicate well-defined detrital flakes, whereas clays are generally present in the rock as fine-grained material in intergranular patches and networks. The rock shows fairly well-defined bedding which is laminar and on a scale of a few millimetres. The bedding is defined generally by variations in the relative proportions of detrital material and clay.

In the quartz-rich parts of the rock quartz and feldspar form grains up to 0.09 mm in size; these grains are generally well-sorted, but they are characterized by their angular shape which is probably largely the result of localised pressure solution and deformation. In many places the grains have long and concavo-convex boundaries and tangential contacts appear to have been virtually entirely eliminated. Clays are therefore present in this part of the rock, in small, intergranular patches which are extremely fine-grained. Detrital muscovite and biotite commonly form contorted flakes up to about 0.12 mm in length. These flakes have a common orientation parallel to the bedding in the rock. Typical fields of view in this part of the sample contain about 75-80% of quartz and approximately 5-10% of detrital mica flakes.

Elsewhere, the rock is somewhat finer-grained and contains both more detrital mica and more fine-grained clay material. In other respects, however, these parts of the rock are similar to the siltstone just described. The clay material in all parts of this section is generally more or less colourless and shows low birefringence colours, and therefore appears to be rather more kaolinitic than the birefringent illite described in the rock above. These identifications would need to be confirmed by X-ray diffraction analysis.

It is difficult to decide whether the rock is suitable for whole rock Rb-Sr geochronology since there is a small amount of detrital mica. This may give a somewhat older age than that of the (probably recrystallized) clay material.

Sample: P899/78: TS40526 6937 RS 40

Location:
Bumbarlow No. 1, 644.65 m.

Rock Name:
Silty shale

Thin Section:
This sample is similar to the rock from 642.3 m, but it shows a smaller range of variation. As far as can be determined optically, the rock contains less than 20% of detrital quartz and feldspar and of the order of 20-30% of detrital mica, with the remainder of the rock composed very largely of extremely fine-grained clay material. These components are closely intergrown and in many parts of the thin section it is not possible to give either a detailed mineralogy or texture.

There are one or two thin (less than 1 mm) beds of siltstone and these consist of subequal amounts of detrital quartz, mica and patches of fine-grained clay. The quartz grains in this part of the rock are generally not more than 0.05 mm in size but they appear to have been fairly well sorted. Some of the grains have rather irregular outlines, probably due to partial resorption by clay material. Detrital biotite is apparently more abundant than muscovite in these parts of the rock and it forms an almost contiguous network of green pleochroic flakes, commonly as much at 0.08 mm in length. These flakes have a well-defined orientation. Clay, in contrast, tends to form small, subequant patches of extremely fine-grained birefringent material which is probably illitic. These patches are irregular and are interpreted as being remnants of a muddy matrix rather than, for example, alteration products of feldspar.

In the bulk of the rock there is much more fine-grained, turbid clay and details of the texture are rather difficult to see. There are silt-grade grains of quartz and these are generally equant in shape, whereas detrital micas retain a preferred orientation and subequant shapes. In all parts of the rock micas show a preferred orientation parallel to the bedding of the rock. Clays generally to not show a bulk extinction and it appears, therefore, that the small flakes have a random distribution. The argillaceous parts of this sample are probably suitable for geochronology, and it is likely that, in the sample taken as a whole, recrystallized, illitic material predominates to such a great extent over detrital biotite and muscovite that a reasonable Rb-Sr age could be obtained.

Sample: P900/78; TS40527 6937 RS41

Location:
Bumbarlow No. 1, 644.76 m.

Rock Name:
Silty shale

Thin Section:
Apart from one bed about 8 mm in width, this is a clay-rich shale which is extremely fine-grained. Few textural details can be determined. The bed referred to above is somewhat more silty in composition, but even so, probably contains no more than about 20% detrital quartz and feldspar. There are a few small lenses of similar material, but fully 75% of the sample consists of shale.

The shale is brown in plane polarized light and shows faint bulk extinction. There are rare quartz grains up to about 0.02 mm in size, but apart from these the sample appears to consist of extremely fine-grained material which is interpreted as being argillaceous. Detrital micas are possibly present but well-formed flakes could not be seen and it seems reasonable to suggest that most of the material is recrystallized, argillaceous mud and hence would be suitable for Rb-Sr geochronology. The siltier beds contain quartz grains up to about 0.05 mm in size and these are equant but rather angular grains which do not form an efficient framework. There are flakes of detrital biotite and muscovite in this part of the rock, but these do not comprise more than about 15% of the sample and the flakes show a poor preferred orientation parallel to the overall banding in the rock.

In brief, therefore, this sample consists very largely of birefringent clays (?illite) with well-defined but minor beds of siltier material. The sample is suitable for whole rock Rb-Sr geochronology since detrital micas are present only to a very small extent.

6937RS52

Sample: P901/78; TS40528

Location:
Bumbarlow No. 1, 645.35 m.

Rock Name:
Silty shale

Thin Section:
This sample contains approximately 5-10% of detrital quartz and the remainder consists of birefringent phyllosilicates. The latter are generally extremely fine-grained and it is not likely that the sample contains more than about 5% of detrital biotite and muscovite. Much of the material is probably neoformed illite or a similar phase.

The bulk of the sample is pale brown to dull green in plane polarized light and consists of extremely fine-grained, birefringent phyllosilicates. These show only a very weak bulk extinction and it is likely, therefore, that the material has a granular, random structure. In some places, specific flakes of phyllosilicates can be seen and these are interpreted as being of detrital origin. Most of this material is colourless muscovite but there are turbid green and brown biotites also. The latter mineral shows pleochroism and a moderate birefringence and hence is fairly fresh. It is likely that the detrital material is not sufficiently abundant to prevent Rb-Sr geochronology of the rock. The detrital biotite and muscovite appear to be a little more abundant in the relatively quartz-rich beds of the rock, but these are not well-defined and the sample has a much weaker laminar structure than many other rocks in this collection.

In general, the grains of quartz are widely distributed throughout the rock and in no way form a framework. Most grains are less than 0.06 mm in size and are equant but irregularly shaped. There are a few places where quartz comprises possibly as much as 30% of the volume of the rock, but these are indefinite bands best described as silty shale.

This is a fairly homogeneous shale consisting very largely of a turbid, birefringent clay, tentatively interpreted as being illitic. As far as can be determined, detrital micas are present in accessory amounts only.

Sample: P902/78; TS40529 6937 RS 43

Location:
Bumbarlow No. 1, 645.84 m.

Rock Name:
Silty shale

Thin Section:
In many respects, this sample is similar to other fine-grained sediments in this collection and it is estimated that about 10-20% of the section consists of silty material and the remainder is fine-grained, argillaceous shale.

The abundant phyllosilicates are birefringent and are interpreted as being fine-grained, illitic material. This can be distinguished from discrete flakes of mica which have probably been deposited together with the small amount of detrital quartz. Biotite is probably about as abundant as muscovite, and each mineral comprises approximately 5-10% of the volume of the rock. The biotite generally shows pleochroism in shades of brown, but some is rather turbid and green and some appears to be altered and partly replaced by opaque and semi-opaque material. The flakes of detrital mica show a fairly well-defined orientation parallel to the bedding in the rock. The micas are most prominent in the coarser-grained and more quartz-rich beds. These are argillaceous siltstones containing possibly as much as 50% of detrital quartz. The grains of this mineral are equant and angular and are not more than 0.08 mm in size. Where the grains are in contact there are generally long or concavo-convex boundaries, indicating some compaction and pressure solution. More commonly, the quartz grains are separated from each other by films or aggregates of fine-grained, illitic material.

In the most argillaceous parts of the rock the sample is dark between crossed nicols and shows a faint bulk extinction. This part of the rock probably consists essentially of a homogeneous aggregate of extremely fine-grained ?illitic material with minor relics of detrital micas and a few small patches and lenses of opaque and semi-opaque material. The predominance of this lithology suggests that the sample is suitable for whole rock Rb-Sr geochronology since it is likely that this neoformed illite is much more abundant than the detrital mica.

The sample shows laminar bedding on a scale of less than 1 up to about 3 mm. The beds are generally not sharply defined but have small-scale gradational contacts. There is a complete range, from beds containing 50% quartz to those which are essentially quartz-free.

6937 RS44

Sample: P903/78; TS40530

Location:
Bumbarlow No. 1, 646.1 m.

Rock Name:
Shale and silty shale

Thin Section:
This sample is very similar to the rocks described immediately above and hence, a detailed description will not be given. The bulk of the rock consists essentially of illitic shale with only trace to accessory amounts of detrital quartz and micas. Within this essentially homogeneous lithology are laminar but not very well defined beds of a somewhat more silty material. In these beds there are quartz grains up to approximately 0.06 mm in size, but these do not comprise more than about 30-40% of any one field of view. The quartz grains appear to have been compressed together and are now angular and characterised by the abundance of long contacts. Associated with the quartz in these silty horizons are patches of fine-grained illitic material, opaques and semi-opaques, and a few flakes of detrital muscovite and biotite. There are rare grains of tourmaline also.

For the most part the sample has an essentially laminar structure, but in one place there appears to have been localized squeezing of a silty bed and this has penetrated upwards into the intervening shales. The apophysis of silty material is about 2 mm in length and 1 mm in width.

The sample consists very largely of what is presumably authigenic (neoformed) illite and hence the sample would be suitable for whole rock Rb-Sr geochronology.

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4 July 1978

6937 RS 47 → 52
(P799 → 804/78)

6937 RS 37
(P 805/78)

Director-General,
Department of Mines & Energy,
PO Box 151,
EASTWOOD, SA 5063.

Attention: Fossil Fuels Division

REPORT GS 4326/78

YOUR REFERENCE:	Application dated 7 June 1978
MATERIAL:	7 core samples
LOCALITY:	Bumbarlow No. 1 Stratigraphic Well, Lake Frome area
IDENTIFICATION:	P799/78 - P805/78
DATE RECEIVED	7 June 1978
WORK REQUIRED:	Petrography (6MA1.3) and suitability for geochronology (comparison with samples P217/65 and P218/65; TS16147-8)

Investigation and Report by: Frank Radke

Manager, Geological Services Division: Dr Keith J. Henley

Keith Henley

for Norton Jackson
Managing Director

jd/10

PETROGRAPHY OF SEVEN SAMPLES FROM THE BUMBARLOW NO. 1 WELL

1. SUMMARY

Seven rocks from the Bumbarlow Stratigraphic Well (Lake Frome area) are described and given the following rock names:

Sample and TS No.	Rock Name
P799/78 TS40380	Chloritized basalt
P800/78 TS40381	Altered dacite
P801/78 TS40382	Altered basalt
P802/78 TS40383	Altered dacite
P803/78 TS40384	Altered igneous rock
P804/78 TS40385	Basaltic andesite
P805/78 TS40386	Shale

2. PETROGRAPHY

Sample: P799/78; TS40380 564.00 m

Rock Name:
Chloritized basalt

Hand Specimen:
A dark rock with an irregular, variegated texture.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Chloritic matrix	50
Quartz	20
Chlorite (vesicle fillings)	15
Carbonate	10
Titanium mineral	1
Opaques and semi-opaques	5

This sample consists mainly of a pale green, chloritic matrix through which ovoid structures considered to represent filled vesicles are disseminated. The chloritic matrix has a very fine, weakly fibrous character and locally exhibits a vague foliation. The matrix also contains finely divided intergrowths of opaque material which locally form granular aggregates up to 0.1 mm in size but elsewhere form finely divided grains disseminated through the chloritic matrix producing a variety of matrix textures.

The vesicles are filled mainly with quartz (microcrystalline silica), chlorite and carbonate and these fillings often have a concentrically zoned character. Most of the vesicles have somewhat round to elongate oval shapes but a few particularly some chlorite-filled vesicles have very elongate, lenticular shapes. The chlorite within the vesicles has a fibrous, radial structure and many of the larger chlorite-filled vesicles consist of several concentric bands of fibrous chlorite. This chlorite has a pale green weakly pleochoric colour and low birefringence. The quartz forms very fine, cherty aggregates or fibrous chalcedonic aggregates while the carbonate generally forms relatively coarse crystals up to 0.5 mm in size. The vesicles which show mineralogical zoning generally exhibit outer margins of chlorite with quartz cores or a quartz filling with a carbonate core. This suggests that the paragenetic sequence of the vesicle fillings is from early chlorite then to the deposition of quartz and followed by the deposition of carbonate.

Although most of the quartz and carbonate is concentrated as vesicle fillings, minor quartz and trace to accessory amounts of carbonate are also intergrown with the chloritic matrix. The quartz tends to form polycrystalline aggregates which generally exhibit small, prismatic shapes (up to 0.2 mm long) suggesting that they represent silicified feldspar crystals. The carbonate forms narrow vein fillings and polycrystalline aggregates up to about 1 mm in size. Much of the carbonate intergrown with the matrix has a translucent reddish brown colour due to finely divided inclusions. A similar translucent colour is also present in some of the carbonate vesicle-fillings.

A translucent titanium mineral with high briefringence is disseminated

as prismatic crystals up to 0.2 mm long and turbid polycrystalline patches and vein fillings. A few prismatic crystals of this titanium mineral also occur intergrown with quartz as vesicle-fillings. In some cases this titanium mineral forms small radiating aggregates of prismatic crystals.

A single vesicle was noted containing a narrow rim of intergrown chlorite, quartz and carbonate and core filling consisting mainly of opaque to translucent, reddish brown iron oxides intergrown with microcrystalline silica which forms small spherulites (below 0.1 mm in diameter) which have a well developed radiating character.

564.00 m

This is a basaltic rock with a well developed remnant vesicular texture which has had its matrix almost completely replaced by chlorite. The sample is too highly altered to be suitable for radiometric dating.

Sample: P800/78; TS40381 568.90 m

Rock Name:
Altered dacite

Hand Specimen:
A massive, essentially aphanitic rock with some round vesicular structures up to about 3 mm in diameter. A few very elongate, large vesicular structures up to 1 cm wide and several centimetres long are filled with milky grey quartz. Microchemical tests (staining with sodium cobaltinitrite after a hydrofluoric acid etch) indicates the matrix contains abundant potash feldspar.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Felsic matrix	80
Quartz	5
Calcite	5
Opaques and semi-opaques	10

This sample consists of a very fine-grained, felsic matrix comprised mainly of turbid felsic mineral grains believed to represent potash feldspar intergrown with altered feldspar laths considered to represent altered plagioclase laths. The turbid potash feldspar grains contain finely divided inclusions, which most likely represent iron oxides and tend to occur interstitially between the altered plagioclase laths. The altered plagioclase laths exhibit random orientation and are up to 0.4 mm long. These laths have been largely replaced by finely divided clay or micrystalline silica.

Several ovoid to round vesicular structures are filled mainly with quartz which forms granular aggregates with a typical grain size between 0.1 and 0.5 mm. The larger vesicle also contains a core of coarsely crystalline (typical grain size 2 mm) calcite. Many of the quartz-filled vesicles exhibit concentrations of translucent reddish brown iron oxides around their margins and a few vesicles contain moderate amounts of intergrown translucent iron oxides. Minor calcite is also disseminated through the rock mainly as finely granular fracture and vein fillings up to 0.2 mm wide. Minor quartz is also disseminated through the rock as anhedral grains up to 0.3 mm wide.

Abundant opaque translucent reddish-brown iron oxides are intergrown with the felsic matrix and locally form somewhat elongate crystals and crystalline aggregates up to 0.15 mm in length.

568.90 m This is a fine-grained extrusive igneous rock which locally exhibits well developed vesicles and appears to have an intermediate to acid composition. The sample is too highly altered to be suitable for radiometric dating.

Sample: P801/78; TS40382 575.45 m

Rock Name:
Altered basalt

Hand Specimen:
A massive, reddish-brown coloured rock with a few discontinuous dull white vein and fracture fillings. Microchemical tests (staining with sodium cobaltinitrite after a hydrofluoric acid etch) indicate the matrix contains some intergrown potash feldspar.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Altered plagioclase	50
Chlorite	35
Potash feldspar	7
Carbonate	3
Opaques and semi-opaques	5

This sample consists mainly of randomly oriented, altered plagioclase laths intergrown with interstitial chlorite. The plagioclase laths are up to 0.5 mm in length and exhibit alteration to finely divided sericite-clay.

The chlorite has a very pale green colour with very low birefringence and forms irregular patches up to 0.8 mm in size. The chlorite tends to form structureless to weakly fibrous masses, some of which exhibit a vague radial texture. Some granular potash feldspar is intergrown with the chlorite and often has a turbid, reddish-brown colour due to iron-staining. A few irregular chlorite-filled amygdales were also noted locally in the rock.

The carbonate is concentrated in veins which would represent the white veins noted in hand specimen. These carbonate veins have a granular texture consisting of carbonate crystals up to 0.5 mm in size. Minor carbonate is also disseminated through the rock as anhedral grains up to 0.2 mm in size and very fine granular aggregates, some of which are intergrown with altered plagioclase laths. Opaques are disseminated through the rock as anhedral grains and granular aggregates up to 0.1 mm in size which are generally intergrown with the chlorite-rich patches. Opaques are also locally concentrated around the margins of some carbonate veins. Much of the feldspar and chlorite in this rock has a translucent, reddish-brown colour due to limonitic iron-staining which would also account for the red colour of the rock in hand specimen.

575.45m This is a relatively fine-grained basalt which has been extensively altered but still retains a remnant basaltic texture. The alteration has completely replaced the primary mafic minerals by chlorite and has partially replaced the plagioclase by finely divided sericite and minor carbonate. The sample is too highly altered to be suitable for radiometric dating.

Sample: P802/78; TS40383 589.00 m

Rock Name:
Altered dacite

Hand Specimen:
This core interval consists of an aphanitic, massive rock with a colour ranging from a pale green to a darker reddish-brown. The rock is cut by a few randomly oriented fractures but also contains some very straight fractures with a parallel orientation approximately perpendicular to the core axis. Microchemical tests show that the pale green portion of the rock contains abundant potash feldspar and the reddish coloured part of the rock, although still rich in potash feldspar, appears to have a somewhat lower amount. Potash feldspar is also concentrated marginal to some fractures and veins.

Thin Section:
In thin section this rock can be seen to have somewhat variable mineralogy due to alteration and replacement of the original minerals mainly by chlorite, opaques and quartz but the primary texture is still retained. This texture is comprised of small, feldspar microlites which have narrow, elongate shapes and a random orientation disseminated through a matrix. The freshest part of the rock which would consist of the green portion noted in the hand specimen has a turbid, reddish-brown matrix comprised mainly of potash feldspar and in the more altered portions of the rock, the potash feldspar has been partially or completely replaced by chlorite, quartz and opaque iron oxides. The general texture of the matrix is that of a devitrified intermediate to acid volcanic rock and the original rock is believed to have been of approximately dacitic composition, although the extensive alteration makes such an interpretation somewhat tentative.

The veins are filled mainly with calcite, chlorite and quartz. The calcite tends to occur in the central regions of the larger veins as individual grains or polycrystalline aggregates up to 0.5 mm wide. The quartz has a cherty, granular texture and is generally intergrown with veins of structureless to fibrous green chlorite. Chlorite also forms narrow veins below 0.1 mm wide and irregular patches up to 0.5 mm in size.

One completely altered prismatic phenocryst approximately 0.5 mm in size which appears to represent a mafic phenocryst (probably a pyroxene) is now comprised of finely intergrown chlorite and calcite. A few other microphenocrysts completely replaced by chlorite with less well-developed shapes were also noted.

589.00 m This is a highly altered rock believed to be a dacite which shows remnant devitrification textures comprised of large feldspar microlites in a slightly devitrified potash feldspar-rich matrix. The sample is too highly altered to be suitable for radiometric dating.

Sample: P803/78; TS40384 615.00 m

Rock Name:
Altered igneous rock

Hand Specimen:
A variegated rock with a variable range of colours ranging from dark grey to black to pale reddish-brown with a few greenish coloured patches. Microchemical tests indicated the sample contains no potash feldspar.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Chlorite	55
Quartz	30
Carbonate	12
Zircon	trace-1
Opaques and semi-opaques	3

This sample is comprised almost completely of secondary quartz and chlorite which has replaced the original rock leaving very little evidence of its original texture. A few highly altered prismatic crystals which now consist of finely intergrown carbonate and chlorite with minor granular quartz and could represent remnant phenocrysts from an original volcanic rock are the only textural evidence of the original rock type. The alteration has been so pronounced that there is very little indication as to the mineralogy of these original phenocrysts although their shapes suggests that they could represent altered plagioclase phenocrysts and a few could represent altered pyroxene phenocrysts.

Most of the rock consists of a somewhat structureless very weakly pleochroic green chlorite intergrown with granular quartz. Locally the chlorite forms ovoid structures up to several millimetres in diameter which has a radial fibrous texture and well developed concentric zoning best seen under crossed-nicols. Veins comprised of finely granular, cherty silica as well as some carbonate-filled veins transect these chlorite lithophysae and a few also exhibit narrow margins of finely granular, cherty quartz. Most of the quartz forms irregular granular patches up to 0.5 mm in size intergrown with the structureless chlorite. Besides forming narrow fracture and vein fillings the carbonate is concentrated in irregular patches up to 0.5 mm in size which are intergrown with the granular quartz and chlorite. Much of this carbonate has a translucent reddish-brown colour produced by finely divided iron oxides. Opaques are also disseminated through the rock as anhedral grains and granular aggregates up to 0.3 mm in size.

A few euhedral, prismatic zircon crystals up to 0.2 mm in size are disseminated through the rock.

6[illegible]00 m <u>This is a highly altered rock showing little textural evidence as to original rock type although it is most likely a highly altered volcanic rock of intermediate to basic composition.</u>

This rock is unsuitable for radiometric dating because of its highly altered character and abundant carbonate content. The well developed prismatic zircon crystals could probably be dated by the fission track method and will most likely give a minimum age because of the relatively low annealing temperature (about 200°) of zircon with a high radiation damage.

Sample: P804/78; TS40385 634.90 m

Rock Name:
Basaltic andesite

Hand Specimen:
An aphanitic, reddish-grey coloured rock with round to ovoid black structures some of which have a concentrically zoned character and appear to be filled vesicles. Microchemical tests show that the matrix contains moderate amounts of potash feldspar.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Plagioclase	45
Chlorite	30
Potash feldspar	10
Quartz	5
Carbonate	5
Sphene-leucoxene	5
Opaques	2

This sample is comprised mainly of randomly oriented plagioclase laths intergrown with a green chlorite which generally forms irregular patches. The plagioclase laths are up to 0.3 mm long and contain some interstitial potash feldspar and granular quartz. Most of the feldspar has a turbid, pale reddish-brown colour caused by finely divided iron oxide inclusions.

The black, ovoid vesicle fillings noted in hand specimen consist mainly of chlorite which has a well developed fibrous texture and a weakly pleochroic green colour. These chlorite vesicle fillings exhibit well developed radial textures and locally have concentrically zoned characters. Some of the smaller irregular patches of chlorite intergrown with the feldspar-rich matrix exhibit similar radial fibrous and concentrically zoned textures.

The carbonate is disseminated through the rock as anhedral grains and granular aggregates generally below 0.15 mm in size and rarely as narrow fracture and vein fillings below 0.1 mm wide. A finely granular titanium mineral (probably sphene and/or leucoxene) also forms aggregates up to 0.1 mm in size. Some of these granular aggregates have elongate, acicular shapes and are intergrown with opaque material and could represent altered, acicular ilmenite crystals.

634.90 m This is a fine-grained basic igneous rock which has suffered some alteration to completely replace original mafic minerals by chlorite and produce a finely granular titanium mineral. The rock is unsuitable for radiometric dating both because of its somewhat altered character and because of the presence of moderate amounts of carbonate.

Sample: P805/78; TS40386

Rock Name:
Shale 642.90 m

Hand Specimen:
A finely laminated rock with a dark, greyish-green colour. Minor sulphide (mainly pyrite with possibly some chalcopyrite) occurs along fractures.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Sericitic matrix	90
Quartz	8
Muscovite	1
Biotite, chlorite	trace
Zircon, tourmaline, rutile	trace
Opaques	1

This sample consists mainly of a recrystallized, argillaceous matrix now comprised mainly of finely divided sericite but it does contain some silt to fine sand detrital particles which tend to be concentrated in narrow bands defining a lamellar bedding. The finely divided sericitic matrix has a felted, interlocking character with no well developed foliation direction oriented parallel to the banding.

Quartz is the major detrital mineral forming angular grains generally below 0.1 mm in size although a few detrital quartz grains up to 0.2 mm in size are also present. Traces of detrital microcline as well as a few well developed flakes of muscovite and biotite which are also believed to be of detrital origin were also noted. Biotite shows some alteration to pleochroic green chlorite and a few well developed pleochroic green chlorite flakes were also noted which could represent completely chloritized biotite. Detrital heavy minerals consist of trace amounts of zircon, pleochroic green tourmaline and rutile.

Opaques are disseminated through the rock as anhedral grains and granular aggregates below 0.05 mm in size.

642.90 m This is a fine-grained argillaceous sediment with a matrix now consisting mainly of finely divided sericite and possibly some chlorite and/or clay. The rock is suitable for rubidium-strontium dating although it does contain some detrital potassium minerals such as microcline, muscovite and biotite.

3. COMPARISON WITH SAMPLES P217/65 & P218/65

It was also requested to compare these samples with samples P217/65 and P218/65 (TS16147-8). Both these samples are immature detrital sediments containing abundant angular volcanic rock fragments including some basic volcanic rock fragments. They also contain some acidic rock fragments including tuffs (ignimbrites) with remnant shard structures and a few quartz phenocrysts. Neither of these rocks show any affinities with the volcanic rocks described in this report.

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19 July 1978

6937 RS 53 → 67

Director-General,
Department of Mines & Energy,
Post Office Box 151,
EASTWOOD, 5063.

Attention: Ms B. Youngs

PART REPORT GS4680/78

YOUR REFERENCE:	Application of 28 June 1978
MATERIAL:	Core samples
LOCALITY:	Bumbarlow No. 1
IDENTIFICATION:	P904/78-P918/78
DATE RECEIVED:	30 June 1978
WORK REQUIRED:	Petrography

Investigation and Report by: Dr Brian Steveson

Manager, Geological Services Division: Dr Keith J. Henley

Keith Henley

for Norton Jackson,
Managing Director.

meo/18

EXAMINATION OF SAMPLES FROM BUMBARLOW NO. 1

Sample: P904/78; TS40492

Location:
Bumbarlow No. 1 — 447.00 m

Rock Name:
Conglomerate

Hand Specimen:
The sample is a dark, massive and compact rock which is clearly conglomeratic. Most of the fragments are rather dark and are probably rich in quartz but there are pale green and pink varieties also. The rock appears to contain some cavities which are an integral part of the sample and one surface of the drill core specimen appears to be a shear or fault plane.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Detrital grains:	
Quartz	40–45
Granitic	20
Quartzite	10
Others	5–10
Chert	2
Dolomite	5–7
Opaques	5
Clay/mica	5

This is a rather heterogeneous rock, difficult to describe coherently, but it consists largely of detrital grains and, since some of the softer ones have been squashed during compaction, intergranular material is not abundant. It is, indeed, possible that the dolomite referred to in the list above may well be deformed detrital material, although it now superficially appears to be intergranular.

The most abundant grain type consists of single crystals of quartz and these are commonly up to about 1 mm in size, although they range down to fine sand grade. Most of the grains are equant, but few are more than subangular in shape and there is some evidence of compaction of the grains and development of long and irregular margins. Furthermore, the quartz grains show fairly well-developed optically continuous overgrowths and in some cases these are as much as 0.5 mm in size. Other detrital grain types have been described as granitic; this refers to more or less granular grains which have a coarse texture. Some of these contain a considerable amount of sericitic material, probably derived from the alteration of feldspars, and it seems likely that the grains are derived from granitic or, possibly gneissic, material. Many of these granitic grains are large (more than 3 mm). Quartzite refers to essentially monomineralic grains which show a more or less well-developed mortar texture. These grains are of distinctly metamorphic provenance and in this rock some show extreme foliation and the development of complex sub-grain domains. The quartzite grains are, consequently, generally more or less elongate but some of the smaller ones show subround outlines.

There is one large grain of fine-grained quartz in the rock and this has been referred to in the list above as chert. The average crystal size of the quartz is about 0.03 mm and the rock has a homogeneous and massive appearance. Other grains are fairly dark between crossed nicols and one, at least, appears to be an altered volcanic rock. The material now consists of a mixture of opaques and iron stained argillaceous material, but there are elongate, decussate pseudomorphs of clay after ?feldspar and the presence of these leads to the suggestion that this fragment, at least, may be a basic or intermediate fine-grained volcanic rock. Other fragments are generally smaller and more heterogeneous and generally are composed of fine-grained aggregates of clays, quartz and opaque material. Some of these fragments may be metasediments of some kind; others may be of volcanic origin.

Intergranular material consists of clay/mica in rather heterogeneous, irregular aggregates commonly up to about 0.5 mm in size, one or two patches of coarse-grained dolomite, and abundant, widely dispersed opaque material. It is difficult to assess the extent to which these components have been derived from deformed and altered detrital material, and to what extent they may have been introduced into the rock. The latter interpretation certainly appears to apply to the opaques, but it may not to either the dolomite or the phyllosilicate minerals.

The sample is, therefore, a rather ill-sorted conglomerate and it is likely that most of the material has been derived from granitic or gneissic terrains with which some strained quartzites were associated. In addition, there is good evidence of the presence of some volcanic clasts.

Sample: P905/78; TS40493

Location:
Bumbarlow No. 1 — 507·15 m

Rock Name:
Conglomerate

Hand Specimen:
This is a heterogeneous, dark and massive rock which is clearly a conglomerate. The largest fragment in the hand specimen is several centimetres in size and appears to consist of quartz, whereas other large fragments are fine-grained, green or brown lithologies. All these fragments occur in a fine-grained, sandy matrix which is dark in colour.

Thin Section:
The relative proportions of components depends radically on the sample selected for thin section analysis and hence overall proportions cannot be given. In the thin section the largest fragments consist of argillaceous lithologies which appear to be of sedimentary origin, whereas most of the sandy, detrital material in the matrix is quartz with a minor amount of metasedimentary argillaceous material. There are one or two fragments which may be of volcanic origin.

The largest fragments intersected in the thin section are generally more or less well-rounded and consist of fine-grained argillaceous lithologies, and one of these is an argillaceous siltstone containing detrital quartz and muscovite fragments embedded in an abundant ?kaolinitic matrix. Other fragments appear to be essentially monomineralic and consist of oriented flakes of phyllosilicate. In some places biotite flakes can be seen, but for the most part this rock probably consists of clay. The fragments composed of these metasediments have smooth sides and are generally well-rounded and homogeneous. They comprise fully 50% of the area of the thin section. Other large fragments consist of opaque-rich material and other dark (iron-stained) components. One or two of these fragments could well be of igneous origin, since there are indefinite pseudomorphs after ?feldspar. Other fragments appear to be iron-rich, argillaceous, fine-grained sediments. Many of the smaller argillaceous fragments have been compressed and distorted during the compaction of the rock.

The bulk of the matrix (apart from the distorted, argillaceous fragments) consists of grains of quartz which range in size commonly from 0.2 to 0.8 mm. Many of these quartz grains have relatively large overgrowths and it appears likely that the original grains were subangular to angular in outline. The overgrowths give the quartz grains an angular appearance and there are numerous long and irregular grain margins. Minor components of the finer-grained part of the rock are clays (?matrix) and fine-grained opaque material. Carbonate appears to be absent.

The sample is therefore a conglomerate and the large fragments are either quartz (as shown in the hand specimen) or fine-grained, argillaceous, sedimentary or metasedimentary lithologies. These occur in a groundmass which is essentially an immature sandstone containing numerous, argillaceous, lithic clasts. There is some evidence of a few highly altered, large volcanic fragments(?).

Sample: P906/78; TS40494

Location:
Bumbarlow No. 1 - 509.80 m

Rock Name:
Basic volcanic rock

Hand Specimen:
This sample is an altered, brown rock which is massive and compact. The cut surface has a rather indefinite, speckled appearance.

Thin Section:
This is an extremely altered rock consisting largely of opaque and semi-opaque material and more or less iron-stained clay. Despite this, however, there are sufficient pseudomorph textures to indicate that the sample was originally some kind of basic volcanic rock.

Textures can be seen particularly in relatively pale parts of the rock where opaques and semi-opaques comprise only about 50% of the sample. Here, there are pseudomorphs of clay after laths of plagioclase. These laths were clearly generally about 0.1 to 0.2 mm in size and had a decussate arrangement typical of basic volcanic rocks. The material between these pseudomorphs consists of clays and possibly patches of secondary cryptocrystalline silica. In some places there are aggregates of a mineral showing fine-grained, radiating textures and this may well be chalcedony. Also present is fairly abundant opaque and semi-opaque material and in some cases this forms the whole of the material surrounding the pseudomorphs after plagioclase.

In darker parts of the rock the relict volcanic texture is not as well shown, but there are a few places where enough remains to indicate that the whole of the rock is volcanic and that it does not consist of, for example, a sedimentary rock with a large volcanic fragment. In the darker parts of the rock opaques comprise fully 80% of the sample, the remainder being iron-stained, birefringent clays.

The sample is interpreted, with confidence, as being a basic volcanic rock of some kind which has undergone extensive alteration, and possibly the introduction of ferruginous material. The sample is too altered for geochronological purposes.

Sample: P907/78; TS40495

Location:
Bumbarlow No. 1 -518.40 m

Rock Name:
?Volcanic rock

Hand Specimen:
This sample is a brown to purple coloured rock which is massive and compact. There are rather characteristic irregular patches up to about 3 mm in size.

Thin Section:
This is an extensively altered rock consisting of iron-stained quartz and clays and rather characteristic, elongate, opaque crystals (?hematite). The presence of these crystals, the homogeneity of the rock, and the overall amount of iron suggest that it is probably of volcanic origin but there is little specific textural evidence of this and the interpretation is based as much on the absence of sedimentary features as on any positive indications of a volcanic origin.

The sample is fairly homogeneous and consists of turbid fine-grained material, brown to pink in plane polarized light. Much of this material is probably phyllosilicate of some kind and it is even possible that there is a moderate amount of secondary, fine-grained carbonate. Within this are more or less clear patches of quartz extending commonly up to about 0.2 mm in size. These patches are invariably irregular in shape and generally contain crystals not more than 0.1 mm in size. ?Sericitic material occurs within these patches and may represent altered crystals of a pre-existing feldspar.

Opaques occur largely in specific patches which clearly correlate with the dark patches described in the hand specimen. These patches are generally 1-2 mm in diameter and contain about 80% of opaques within which are small patches of quartz and ?clay. A minor amount of the opaques in the rock occurs as elongate crystals with a notably random distribution and a decussate arrangement. Typically, the elongate crystals are about 0.2 to 0.4 mm in length and their habits suggest that they may well be hematite.

A more detailed description of this rock cannot be given from optical examination alone because of the extent of iron-staining in the bulk of the sample. It is tentatively suggested that the rock is a volcanic of some kind. The rock is far too altered for geochronology.

Sample: P908/78; TS40496

Location:
Bumbarlow No. 1 - 527.50 m

Rock Name:
Banded argillaceous shale

Hand Specimen:
The sample is a somewhat fissile rock which consists of alternating bands of green and purple shale. The bands are of the order of about 2 to 10 mm in width.

Thin Section:
It is not possible to give an overall mineralogy of this rock since the thin section contains numerous bands which vary somewhat from place to place. In general, the sample contains abundant clay and 10-50% of quartz in different bands. Minor components of the rock are ferruginous opaques and small amounts of introduced carbonate.

Probably the most abundant lithology in the rock is a siltstone which contains about 35-40% of quartz, having an average grain size of about 0.08 mm. The quartz grains are generally equant but angular in shape, probably partly due to corrosion by the clay. Other detrital components of this rock are potassium feldspar (which is fresh) and flakes of muscovite and green biotite. The clay in this lithology is homogeneous and has a moderate birefringence and is probably illite or sericite. Small patches of dolomite are widely distributed through this siltstone.

The other abundant lithology is much finer-grained than that described above and contains abundant clay/mica. The quartz is similar in size and shape, but feldspar is absent and there is only a small amount of identifiable, detrital muscovite. The clays have a moderate birefringence and generally show a marked bulk extinction. The bedding in the rock is also shown by the presence of thin lenses and blebs of reddish, semi-opaque and opaque material which is probably ferruginous rather than carbonaceous. In some lithologies this dark material comprises at least 20% of the rock and individual blebs are as much as 0.2 mm in length.

Most lithologies fall between the two extremes described above, but some contain a little more carbonate which is partly confined to conformable, narrow vein systems. The beds are commonly well defined and have sharp bases and tops. The red bands in the hand specimen contain ferruginous material, whereas the green bands are generally composed of subequal amounts of quartz and ?illitic material.

Sample: P909/78; TS40497

Location:
Bumbarlow No. 1 – 534-00 m

Rock Name:
Altered basaltic rock

Hand Specimen:
The sample is a massive and compact brown rock. The cut surface shows complex textures defined largely by variations in the amount of ferruginous material. There are pale blebs up to about 1 cm in size and extremely irregular aggregates characteristically rimmed by ferruginous material. In addition, the sample contains numerous, small, circular and oval features.

Thin Section:
The rock is essentially iron-stained clay with patches of carbonate and slightly clearer material. In addition, there is a considerable amount of secondary quartz. The rock is almost certainly an extensively altered basic igenous rock and this is demonstrated by the presence of both equant and characteristically flattened vesicles. These are now represented either by aggregates of secondary quartz with titaniferous material, or by oval features which have an annular texture and consist of dark, ferruginous material.

The rock has clearly undergone almost complete alteration and it is unlikely that any primary minerals remain. The bulk of the sample is a distinctive yellow-brown colour in plane polarized light and is generally dark between crossed nicols. This is no doubt some kind of clay mineral but it is impossible to estimate which from optical examination alone. Dolomitic material is associated with this clay, but tends to occur in particular areas and veins and is therefore interpreted as having been introduced into the rock. In some places in the thin section the dolomite also occurs in characteristically rounded areas, which are interpreted as vesicles.

The rock contains a little sedimentary material, generally in specific patches. These consist of argillaceous sandstones and it is not clear to what extent they represent genuine xenoliths in the rock, or possibly material introduced during the alteration of the sample. Certainly, the quartz grains have a subrounded appearance and occur in a clay matrix which is paler in colour than the abundant clay in the basalt.

No more information can be given from a petrographic description of this rock as a result of the advanced stage of alteration. Textures are sufficiently similar to other rocks described by Amdel to indicate that the rock is of volcanic origin and was probably a basalt. The rock does contain patches of what appears to be sandstone, and this probably represents xenoliths introduced at the edge of a basalt flow.

Sample: P910/78; TS40498

Location:
Bumbarlow No. 1 — 564·00

Rock Name:
Altered vesicular basalt

Hand Specimen:
The sample is a dark, massive and compact rock and the cut surface shows complex textures. In some places there are equant, sub-round structures up to about 5 mm in size, but elsewhere there appears to be introduced secondary material in more irregular and larger aggregates.

Thin Section:
The rock consists of approximately equal amounts of groundmass altered basaltic material and vesicle in-fillings. At one end of the thin section the rock contains a mixture of dolomite and secondary quartz which appears to represent a relatively large aggregate of introduced material.

The basaltic material consists of a dark, translucent fine-grained aggregate which is black between crossed nicols. In one or two places there are shadowy pseudomorphs of elongate crystals and it is likely that these were originally plagioclase laths. Apart from this it is difficult to give precise details of the nature of this part of the rock and it is supposed to be a basalt on its general appearance and the presence of a large number of in-filled vesicles. As far as can be determined, this part of the rock now consists of an extremely fine-grained, dark brown to dark green mineral, partly obscured by irregular patches of ?titaniferous, translucent material.

The vesicles are relatively large and can readily be seen in the hand specimen. Most are filled largely with quartz containing, in some cases, central aggregates of coarse-grained, dolomitic material. Many of the vesicles show a more or less concentric structure with finer-grained material at the margins and equant, granular aggregates of quartz near the centre. Other vesicles have more complex textures with several radial zones of fine-grained material, some of which is generally dark. Some of this dark material appears to be a carbonate, partly obscured by ferruginous material, and elsewhere there is a green ?carbonate (?malachite). Most of the zoned vesicles have central patches of low temperature, chalcedonic quartz. One or two vesicles in the thin section contain, in addition, a virtually homogeneous central aggregate of a green mineral.

In one part of the thin section the vesicular basaltic material appears to have been invaded on a large scale by an aggregate of approximately equal amounts of dolomite and chalcedonic quartz. These minerals are complexly intergrown with the chalcedony typically forming equant but irregular patches within a contiguous mosaic of slightly iron-stained dolomitic material. In most places this aggregate is bordered by a clear rim of chalcedony about 0.4 mm in width.

This is a thoroughly altered rock, but there appears to be sufficient textural evidence to suggest that the original sample was a basic volcanic rock crowded with vesicles. Most of the host rock is now represented by a dark aggregate of ?phyllosilicates and the vesicles contain abundant secondary minerals of which quartz, dolomite, and a green carbonate are the principal varieties.
Two patches of green vesicle in-filling were examined by X-ray diffraction; they proved to be chlorite.

Sample: P911/78; TS40499

Location:
Bumbarlow No. 1 – 595.00

Rock Name:
Altered basalt

Hand Specimen:
This is a massive and compact, fine-grained, green rock. Apart from irregular cross-cutting veinlets, the sample is featureless.

Thin Section:
This is a homogeneous rock which consists essentially of pseudomorphs after plagioclase in a dark, secondary groundmass. None of the original constituents of the rock appear to have survived alteration. The rock is transected by irregular veins of argillaceous material and carbonates.

In a few places in the thin section pseudomorphs after feldspar phenocrysts have survived, and these are present as small (up to 0.8 mm) sub-rectangular crystals now consisting of secondary calcite and quartz. The remainder of the rock contains pseudomorphs of plagioclase crystals which appear to have originally been laths up to about 0.1 to 0.2 mm in length. Identifiable pseudomorphs now comprise no more than about 20% of the volume of the rock and they rest in a groundmass of dark brown and green material. Also present are small, indefinite patches of calcite. This material is notably homogeneous throughout the area of the thin section and probably represents a completely altered, fine-grained mosaic of plagioclase-mafic mineral-ilmenite.

The rock is transected by a wide variety of veins, most of which contain calcite, quartz and a green ?phyllosilicate mineral. The widest veins are of the order of 1 mm in width, but these tend to be distinctly irregular and narrower veins have a more continuous appearance.

The sample is a massive, homogeneous, basaltic rock which apparently contained a small proportion of plagioclase phenocrysts. The rock has been extensively altered but, nevertheless, the igneous texture is well preserved. The sample is not suitable for geochronology.

Sample: P912/78; TS40500

Location:
Bumbarlow No. 1 - 599.10 m

Rock Name:
Altered vesicular basic igneous rock

Hand Specimen:
The sample is a dark brown rock, characteristically containing oval or rounded structures up to about 1 cm in size. These are concentrated partly in some zones rather than others, but most parts of the hand specimen contain some of these round bodies. The rock contains a large number of rather indefinite, narrow veinlets.

Thin Section:
The sample appears to be considerably more homogeneous in thin section than in the hand specimen, and the rock consists very largely of a dark brown, secondary aggregate within which are spherical bodies which appear to be vesicle in-fillings. On the basis of these the sample has been described as a basic igneous rock, but the bulk of the sample is entirely secondary material and it does not show any relict textures.

The rock is a distinctive brown or orange colour in plane polarized light but is densely speckled with semi-opaque material, much of which is probably titaniferous. These speckles are generally on a scale of 0.1 to 0.2 mm and comprise about 30% of the volume of this part of the rock. The remainder is homogeneous and in some places crystals up to about 0.1 mm in size can be seen. The intensity of dark speckling is such, however, that no specific mineralogical identification can be made. It is possible that in some places there is a considerable amount of iron-stained carbonate, but this hypothesis would need to be checked by X-ray diffraction analysis.

Approximately 15-20% of the area of the thin section consists of distinctive, oval or round bodies which are interpreted as being in-filled vesicles. Most of these contain abundant calcite, some of which is unusually coarse-grained. Others contain secondary quartz densely speckled with inclusions. Where these two secondary minerals occur together, the quartz generally occupies the central position within the aggregate of calcite. Most of the larger vesicles have a distinctive rim of opaque material separating the calcite from the bulk of the basaltic material. Some smaller vesicles (up to about 0.5 mm) consist virtually entirely of opaque material.

The sample is interpreted (with some confidence) as being a basic volcanic rock, but it has been now completely altered and any distinctive textures have been obliterated. The sample is not suitable for geochronology.

Sample: P913/78; TS40501

Location:
Bumbarlow No. 1 - 618.90 m

Rock Name:
Altered basalt

Hand Specimen:
This rock is green in colour and is compact and extremely fine-grained. The rock contains a few small veinlets but is otherwise featureless.

Thin Section:
The bulk of the rock consists of an altered basalt which is fine-grained and retains considerable evidence of its original texture. There are also veinlets and in-filled vesicles.

In one place in the thin section there is a patch of material about 0.8 mm in size which is interpreted as being a relict of an original olivine phenocryst. This now consists of quartz and carbonate, but it has a characteristic shape and fracture pattern. Elsewhere there are one or two more rectangular pseudomorphs which are interpreted as being relics of small and sparse feldspar phenocrysts. Apart from these, the rock is fine-grained and relics of plagioclase laths are generally not more than about 0.2 mm in length. Identifiable pseudomorphs of plagioclase comprise about 15-25% of the rock and they have a characteristic, decussate arrangement. Secondary material forms all of the space between the feldspar laths and consists of opaques, green clay, and calcite (in approximately decreasing order of abundance). The green clay is particularly distinctive since it forms clear patches amongst the otherwise rather turbid and iron-stained material. Some of these patches are as much as 0.2 mm in size and they have an extremely fine-grained texture commonly with some evidence of radiating arrangements of the clay. Calcite and opaques are both extremely fine-grained.

The proportions of secondary minerals vary somewhat from place to place in the rock and there are some places where secondary chalcedony and quartz are more abundant than is indicated in the description so far. Secondary chalcedonic material appears to be associated particularly with the region around the cross-cutting veinlets and near one large patch of vesicular material. The vesicles now contain abundant chalcedony and secondary megaquartz, generally rimmed by a small amount of green clay. Beyond these vesicles there are patches of finely granular quartz/chalcedony up to about 0.3 mm in size and elsewhere in the rock similar material is closely intergrown with some patches of green clay.

Veinlets in the rock generally consist largely of coarse-grained calcite rimmed by green clay and finely granular secondary quartz/chalcedony.

The sample is a fairly homogeneous basalt with apparently contained a small proportion of phenocrysts of both olivine and plagioclase. Relics of small plagioclase laths are relatively abundant and are surrounded by wholly secondary material consisting of opaques, green clay, calcite and chalcedonic silica. There are sparse vesicles consisting largely of chalcedony. The sample is not suitable for geochronology.

Sample: P914/78; TS40502

Location:
Bumbarlow No. 1 – 630·50 m

Rock Name:
Brecciated basic volcanic rock

Hand Specimen:
The sample is an aphanitic, dark green rock with a few darker, circular specks. The sample has been brecciated and there are fractures up to about 1 cm in width. These appear to be filled partly with fine-grained, basaltic debris.

Thin Section:
The thin section contains homogeneous, basaltic material and fracture fillings composed largely of quartz/chalcedony and calcite.

The basalt is a fine-grained, homogeneous variety, containing sparse vesicles. The rock has been extensively altered, but relics of plagioclase laths can just be distinguished. These appear to occupy about 50% of the rock and the intervening material is a pale green clay partly obscured in places by semi-opaque, titaniferous material. The plagioclase laths and the aggregates of clay are generally of the order of 0.05 to 0.08 mm in size. Minor constituents of the basalt are small specks of secondary quartz and rare patches of calcite.

Vesicles are commonly about 0.6 to 1 mm in diameter and are invariably smooth-sided and sub-round in outline. Most have relatively complex textures with zoning and contain green clay and/or chalcedony.

The basalt has been fractured on a fairly large scale and the thin section contains a considerable amount of the fracture-filling material. This is mainly secondary quartz which forms a granular mosaic with an average crystal size of approximately 0.05 mm. In many places the mosaic of quartz shows variations in crystal size conformable to the edges of adjacent blocks of basalt. Calcite is a minor secondary component and generally forms large crystals in the centre of the aggregates of quartz/chalcedony. Although more than 90% of the basalt in the thin section occurs as large fragments, there are small blocks completely embedded in the larger aggregates of secondary quartz and these blocks range in size from 0.2 to 0.7 mm.

The sample is, therefore, a homogeneous and completely altered basaltic rock which has been brecciated and the cavities formed have been filled with abundant secondary quartz and minor calcite. The sample is not suitable for geochronology.

Sample: P915/78; TS40503

Location:
Bumbarlow No. 1 — 651.00 m

Rock Name:
Feldspathic lithic sandstone

Hand Specimen:
This is a coarse-grained, pink sandstone which is massive and compact.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Quartz	80
Lithic fragments	15
Feldspar	7

This sandstone has been cemented largely by the development of quartz overgrowths and partly by the deformation of lithic fragments, and it appears unlikely that there is any genuine intergranular material. Quartz is present as angular crystals (as a result of the development of overgrowths), whereas feldspar characteristically retains its original detrital form. The sample was probably derived from relatively coarse-grained and immature detrital material containing relatively abundant feldspar and lithic material. The sample therefore has affinities with arkosic rocks derived from rapidly uplifted granitic or metamorphic terrains and deposited in non-marine environments after only brief transport.

Quartz crystals have a wide size range but there is abundant material coarser than about 0.6 mm. Many of the quartz crystals contain trails of semi-opaque materials defining the original round to sub-round grain outlines. Overgrowths, however, are fairly large and there are some 0.2 mm in width. Some of the quartz is filled with inclusions and shows markedly undulose extinction, but much is of the common or plutonic variety. It appears likely that the original quartz texture was, therefore, generally about sub-round but probably not very well sorted. The feldspar grains give more indication of the nature of the original material since they have clearly not been modified during diagenesis of the rock. The grains are commonly sub-round in shape and they show a similar size range to the quartz crystals. Some of the feldspar shows a little alteration and some grains have been fractured. The secondary products are opaques and calcite. The feldspar ranges from well-twinned microclines to rather turbid and untwinned ?orthocalse.

Much of the more or less dark material in the rock is interpreted as being lithic fragments. One or two of these appear to be silicified igneous rocks, but most are aggregates of quartz, feldspar and sericite more or less obscured by abundant opaques and calcite. The last two minerals are interpreted as being of secondary origin and have selectively replaced the more argillaceous and altered lithic fragments.

As a result of the deformation of the lithic fragments (by squeezing between more rigid quartz crystals) and the development of secondary silica, many parts of the rock have a distinctly granular appearance with some interlocking quartz crystals, and within this mosaic of quartz

and lithic patches are round to sub-round feldspar crystals. As mentioned above, it is unlikely that there is any genuine argillaceous matrix in the rock.

Sample: P916/78; TS40504

Location:
Bumbarlow No. 1 - 667·50 m

Rock Name:
Dolomitic siltstone

Hand Specimen:
The sample is a grey, aphanitic rock which shows fine, laminar banding.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Clay	25-65
Quartz	20-40
Dolomite	5-30
Mica	2-5
Opaques	2

The proportions given above indicate the range of composition of different bands in the rock and are not an attempt to estimate an average. The rock contains several different lithologies, generally fairly readily distinguished from each other in the thin section.

The coarser-grained lithologies are those containing relatively large amounts of quartz and dolomite. The quartz forms equant, anhedral crystals/grains up to 0.08 mm in size and these are intergrown with slightly coarser-grained but more irregular dolomite crystals and patches of brown clay. This part of the rock generally contains rather more micaceous material than do the more argillaceous lithologies. This lithology is therefore a fairly quartz-rich siltstone, partly invaded by authigenic dolomite.

The other principle lithology is a clay-rich rock within which quartz, mica and dolomite are widely dispersed. The quartz grains in this part of the rock are generally not more than 0.04 mm in size and many appear to have been partly replaced by the clay material. The latter is generally dark and turbid in plane polarized light, but it does show a bulk extinction under crossed nicols. The clay has a moderate birefringence but it has been partly stained by ferruginous material and it is not possible to estimate the mineralogical nature of the clay. There are blebs of opaque and semi-opaque material in this part of the rock and it is not clear to what extent these are titaniferous or ferruginous, but they do not appear to be carbonaceous.

There are lithologies intermediate between the two described and these generally contain of the order of 35-50% of clay and smaller, subequal amounts of dolomite and quartz.

The sample is, therefore, a laminar-banded succession of alternating, silty shales and argillaceous siltstones. These rocks contain relatively coarse-grained, authigenic dolomite which has probably been introduced.

Sample: P917/78; TS40505

Location:
Bumbarlow No. 1 - 694·90

Rock Name:
Lithic sandstone

Hand Specimen:
This is a medium to coarse-grained sandstone which is distinctly pale grey in colour.

Thin Section:
An optical estimate of the constituents gives the following:

	%
Quartz	70
Clay	12
Lithic fragments	10
Feldspar	3
Dolomite	3
Opaques	2
Mica	1

This sample is similar to P915/78, except that no specifically volcanic lithic fragments were identified. In addition, the present sample contains a moderate amount of clay, some of which may well represent original argillaceous matrix which has been recrystallized and coarsened. This is deduced principally from the homogeneity of this clay.

Quartz is present as equant but angular and irregular grains/crystals which have clearly been extensively modified during the compaction and diagenesis of the rock. Some crystals show trails of ?clays which define original, ?sub-round, detrital outlines, but this is not common and most of the quartz forms more or less granular mosaics with some patches and intergranular smears of clay. In some places the quartz crystals are closely interlocked along sutured margins. These sutures are not confined to specific zones in the rock but are widely dispersed. Feldspars, on the other hand, tend to retain their original detrital outline and have sub-round to sub-angular shapes. Much of the feldspar is an untwinned variety which shows a moderate amount of alteration and fracturing. It seems likely that the feldspar is of a potassic variety and may well have been derived from granitic or gneissic rocks. Classified under 'quartz' in the list above are a few quartzite grains, many of which are more than 1 mm in size and are characterized by mortar textures and other evidence of intense shearing.

Lithic fragments include a few dark, argillaceous aggregates in the rock and a few granular mosaics more or less obscured by sericitic material. These lithologies are different from the clay ?matrix in the rock which is a homogeneous illitic/sericitic mosaic. Whether the latter has been derived from original lithic fragments is rather difficult to distinguish since the material has been deformed during compaction. It appears from the homogeneity of this material that it is somewhat different from the altered argillaceous lithic fragments. The nature of the latter is rather difficult to determine since they consist of granular aggregates having an average crystal size of about 0.2 mm, and consisting of equant, anhedral crystals essentially obscured by sericitic material.

The rock is probably a metamorphic or altered igneous type of some kind (but not volcanic).

Dolomite occurs in a few places in the rock where it forms distinctly irregular crystals which have no doubt been introduced into the sample during diagenesis.

The rock is therefore interpreted in a similar way to P915/78 in that it appears to be a coarse-grained, immature sandstone with a moderate component of lithic fragments (largely of metamorphic origin, probably) and alkali feldspar. This sample may well have contained some original argillaceous matrix also.

Sample: P918/78; TS40506

Location:
Bumbarlow No. 1 – 711.80 m

Rock Name:
Dolomitic shale

Hand Specimen:
This sample is a black, fine-grained rock with almost laminar bedding. The beds are generally paler and somewhat browner than the bulk of the rock.

Thin Section:
This is a banded heterogeneous rock consisting essentially of alternating beds of dolomitic material and silty shale. The dolomitic beds are clearly the paler and browner lithology in the hand specimen and they range in width up to about 0.6 mm. The wider beds have a notably granular texture and consist of equant crystals about 0.03 mm in size. This appears to be secondary dolomite, probably introduced along preferential zones in the rock. The thicker dolomite beds have a notably bulbous appearance in detail, which may well have been inherited from the original lithology replaced by the dolomite. Despite the pinching and swelling, the beds are continuous across the thin section.

The intervening argillaceous layers generally consist of a birefringent clay (?illite) which shows a notable bulk extinction. The material is extremely fine-grained and details of individual flakes cannot be seen. In some places the illite forms a virtually monomineralic layer, but elsewhere it is intergrown with accessory amounts of detrital quartz and mica. Few quartz grains are more than about 0.03 mm in size, and they do not appear to comprise more than 10% of any one bed in the rock.

The sample contains a moderate amount of opaque and semi-opaque material which appears to be ferruginous rather than carbonaceous. This is generally confined to specific beds rather than large aggregates of any kind.

The sample is, therefore, a thinly-bedded argillaceous sediment which appears to have undergone some dolomitization confined to specific bands.

The sample contains rather a large amount of dolomite, but is probably suitable for geochronology.

APPENDIX 4

Bumbarlow 1

Report of Geochronology

by

Alan Webb

AMDEL

DM1096/72
Exp 2136 Vol II

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The Director-General
Department of Mines & Energy
P O Box 151
EASTWOOD

GEOCHRONOLOGY OF THE
EASTERN BASEMENT ROCKS

Progress Report No. 20

by

A. W. Webb

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GEOCHRONOLOGY OF THE EASTERN BASEMENT ROCKS

1 REVIEW OF PROGRESS

Samples of drill core from Bumbarlow No. 1 and Mutooroo DDH 14B were submitted for examination and evaluation of suitability for Rb-Sr geochronology. The descriptions of these samples were reported in Amdel Report GS 4685/78 (Bumbarlow No. 1) and Progress Report No. 18 for Project 11.07.0357 (Mutooroo). Eight samples of the Bumbarlow core and six of the Mutooroo core were selected for dating and the analytical details and interpretation of the results are given in the following sections of the present Report.

2 GEOCHRONOLOGY

2.1 Sediments from Bumbarlow No. 1

The eight samples came from an interval of approximately 4 metres and represent an interbedded sediment between two of the lava flows intersected in this hole. The Rb-Sr isotopic analyses are listed in Table 1 and plotted in Fig. 1. Linear regression of the data indicated a residual variance in excess of the expected experimental error and produced a Model 2 isochron of 1360 ± 144 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7187 ± 0.0377. A Model 2 isochron is usually interpreted as indicating that the samples are not all of the same age, and in the case of these sediments, possibly indicates the presence of an inherited (detrital mica) age. However, detrital mica was absent from some of the samples and present in varying amounts in the remainder and the most likely interpretation of the isochron age is that it represents the time of deposition of the sediment. The large uncertainty (±144 Ma) reflects a lack of complete homogenisation between the fine and coarser fractions of the sediment during deposition. The age is comparable to the older age limit of the acid volcanics in Mudguard No. 1 and suggests a northwesterly extension of this basement from the Benagerie Ridge.

A significant feature of this result is that there are no signs of updating during the Delamerian Orogeny, whereas the Adelaidean sequence to the west and the pre-Adelaidean Willyama Complex to the south and southeast frequently produce Cambro-Ordovician isotopic dates. This supports the hypothesis that the Curnamona Nucleus was indeed a very stable block during the Delamerian Orogeny.

2.2 Augen Gneiss from Mutooroo DDH 14B

Six samples of the gneiss were analysed; five of these were described as augen gneiss and the sixth as a leucocratic gneiss. The analyses are listed in Table 2 but are not plotted on an isochron diagram because of the lack of a well defined linear relationship. Two of the analyses (P758/78 the leucocratic gneiss, and P759/78) are particularly anomalous.

The remaining four analyses do suggest a linear relationship, and for an initial ratio of 0.700 they would have an approximate age of 1700 Ma. However, because of the poor quality of this alignment, it was not considered worthwhile regressing the data for a more precise result. The date of 1700 Ma would be a maximum age and corresponds roughly with the age of the Broken Hill gneisses but it is obvious that subsequent events have caused these samples to become open systems with respect to Rb and Sr.

TABLE 1

Rb-Sr Analyses - Bumbarlow No. 1

Sample No.	Depth (m)	Rb/Sr	$^{87}Rb/^{86}Sr$	$\#^{87}Sr/^{86}Sr$
P805/78A	642.90	5.418	16.147	1.0358
P805/78B	642.90	6.081	18.185	1.0719
P897/78	642.3	6.220	18.619	1.0826
P898/78	643.67	5.680	16.946	1.0469
			16.946	1.0468
P900/78	644.76	6.479	19.413	1.0926
P901/78	645.35	6.560	19.679	1.1049
P902/78	645.84	6.445	19.312	1.0931
P903/78	646.1	6.597	19.797	1.1087

Ratios normalised to $^{88}Sr/^{86}Sr = 8.3752$

Constants used: $^{85}Rb/^{87}Rb = 2.600$

$\lambda^{87}Rb = 1.42 \times 10^{-11}\ y^{-1}$

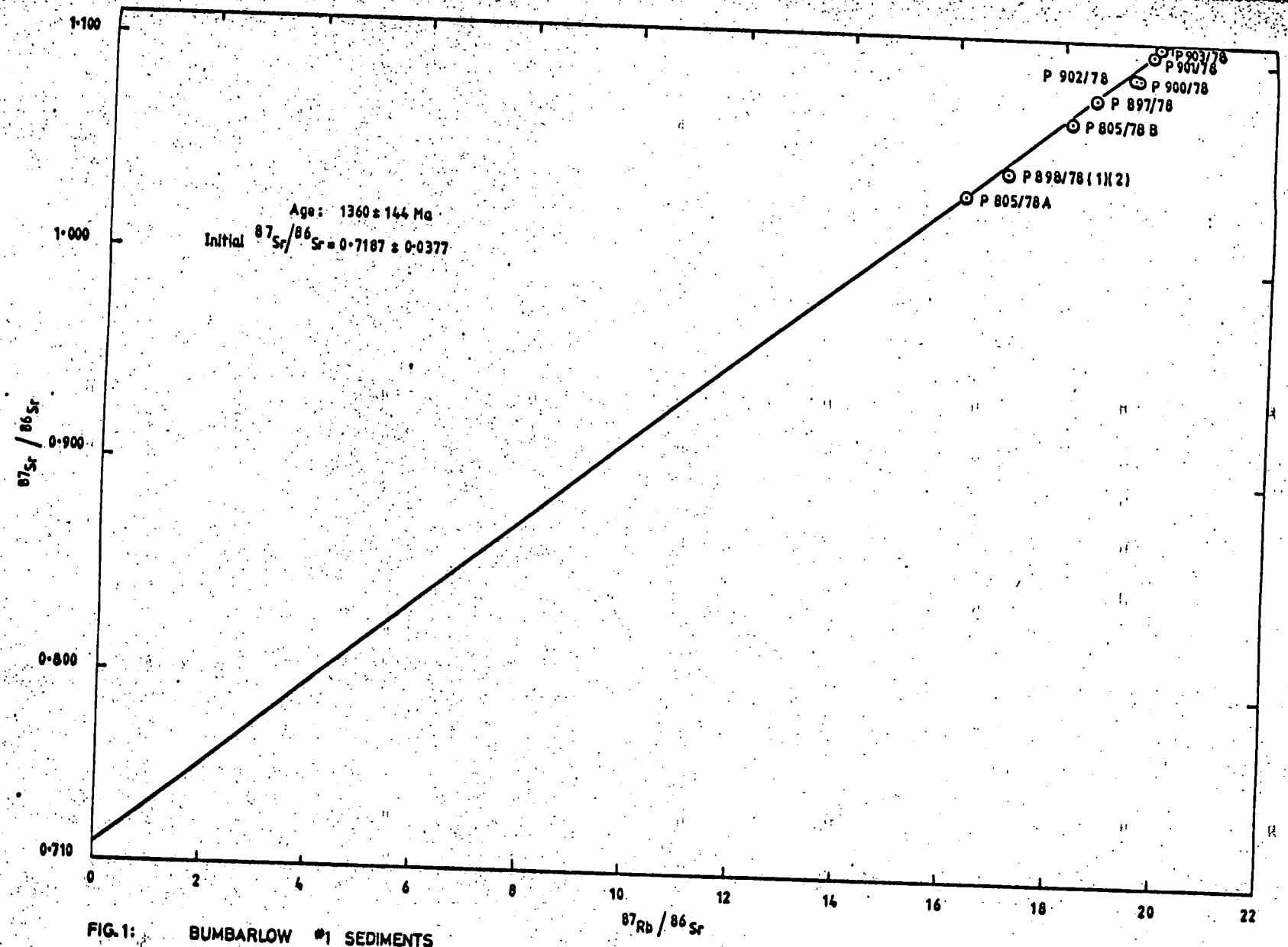
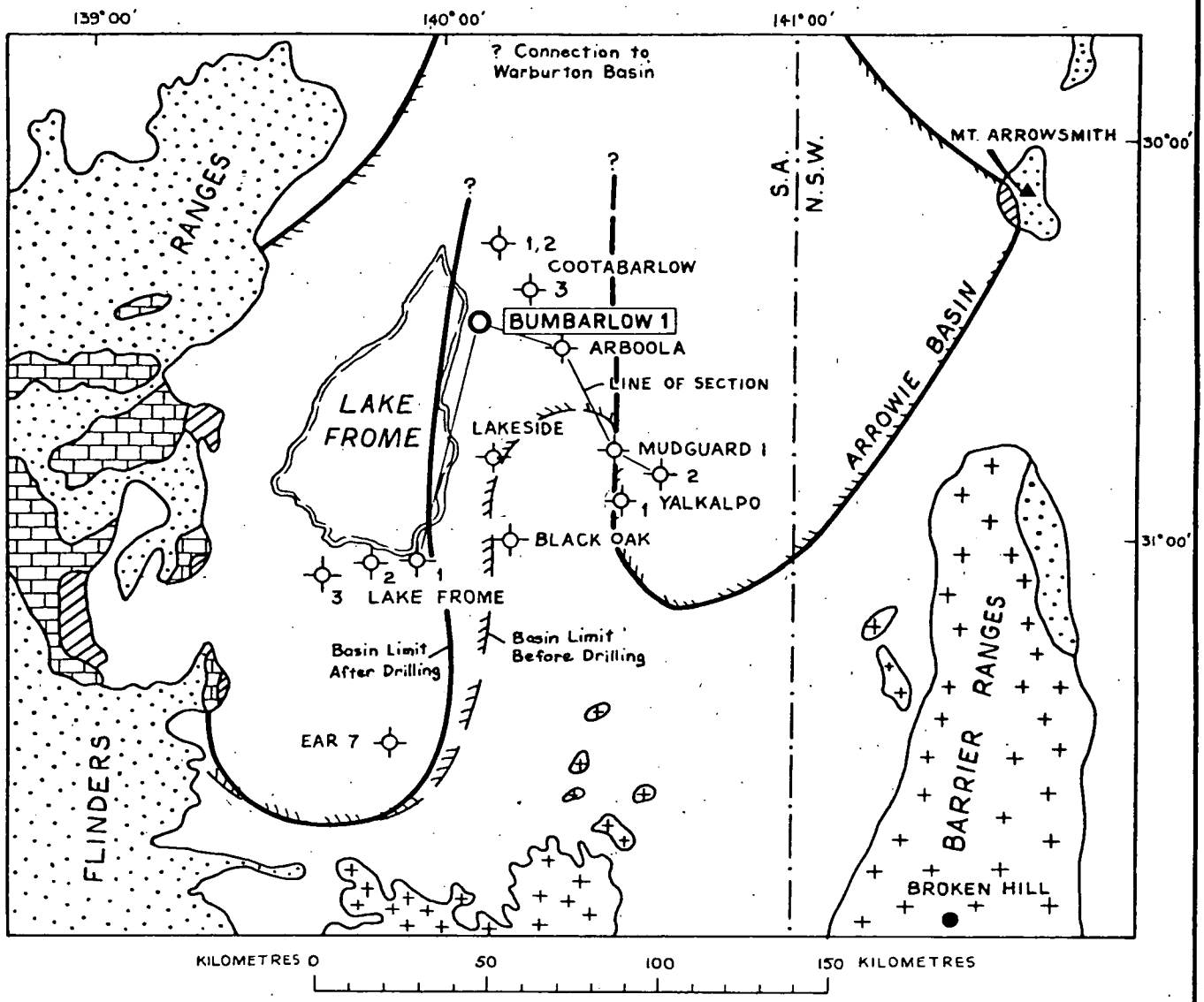


FIG. 1: BUMBARLOW #1 SEDIMENTS



OUTCROPS

Middle - Late Cambrian

Early Cambrian

Precambrian

Crystalline Basement
(Benagerie Ridge - Olary Block)

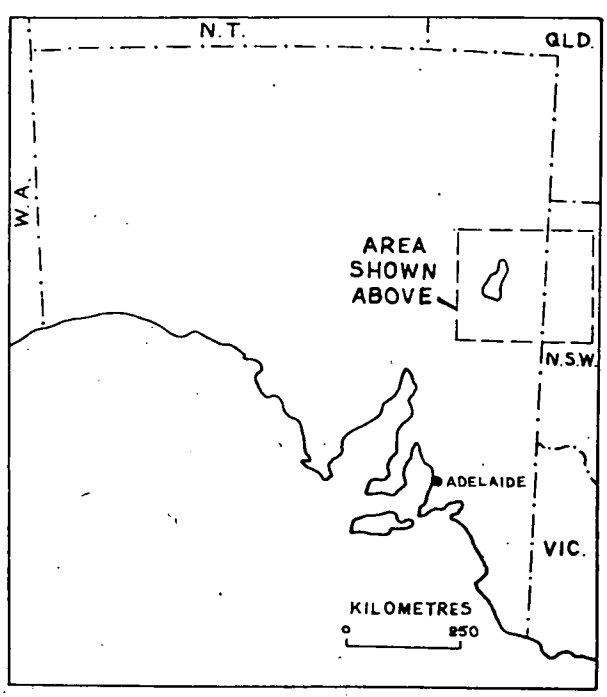
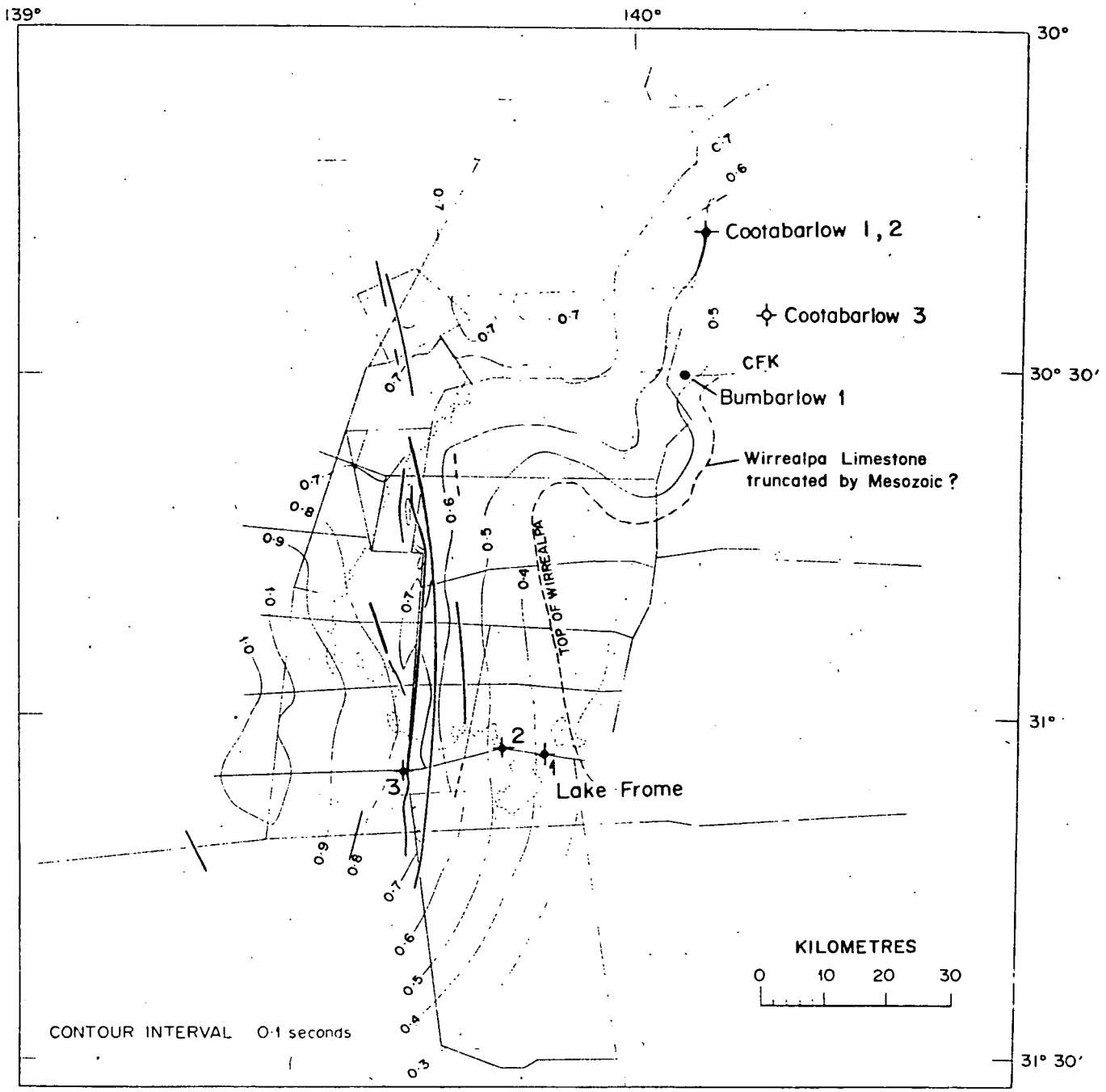


FIG. 1

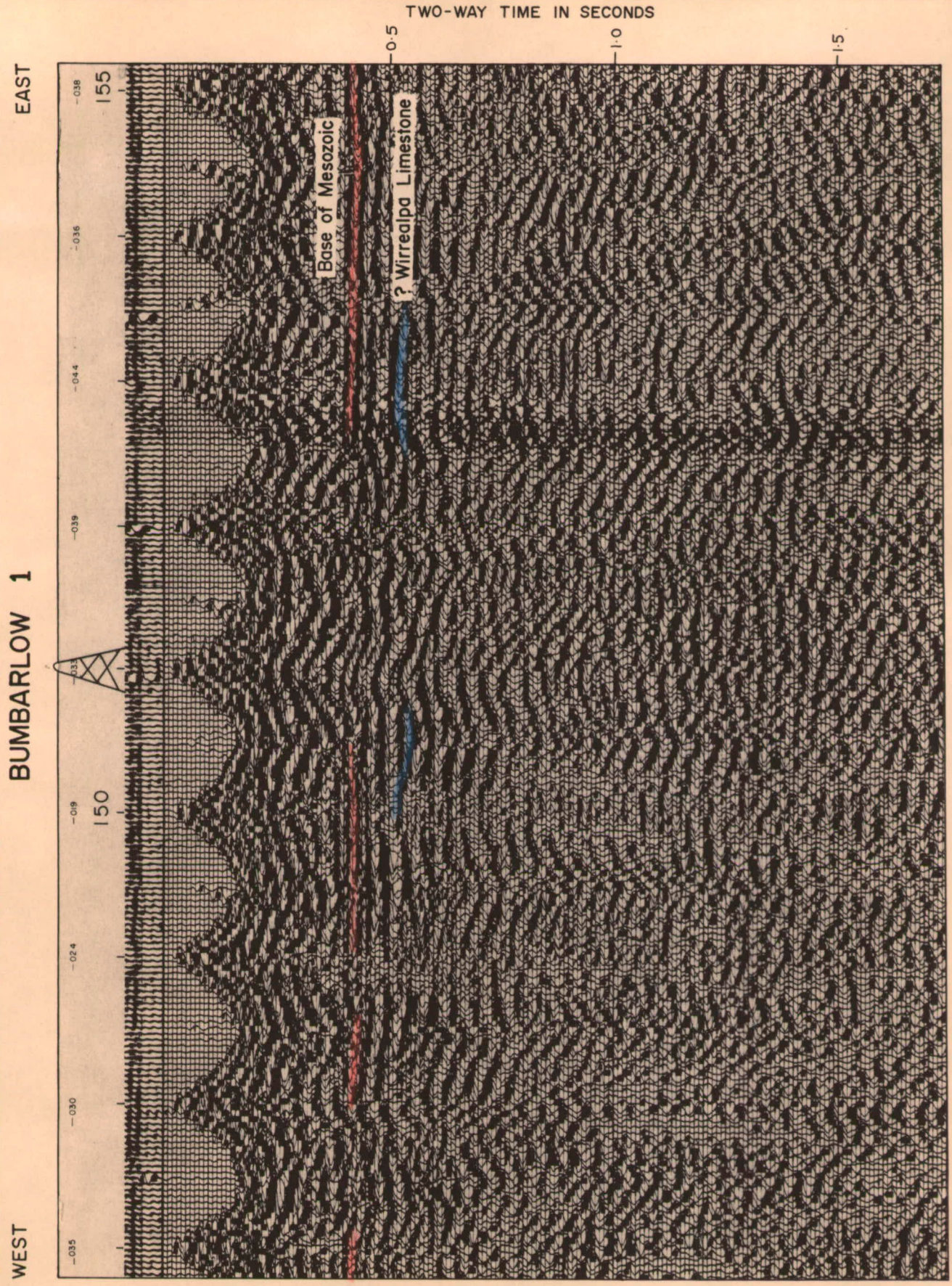
	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE 1:2,000,000
COMPILED B.C. Youngs	EAST ARROWIE BASIN LOCALITY PLAN	DATE 15-9-78
DRN K.W. CKD		PLAN NUMBER S13619



(Results from Crusader 1971)

FIG. 2

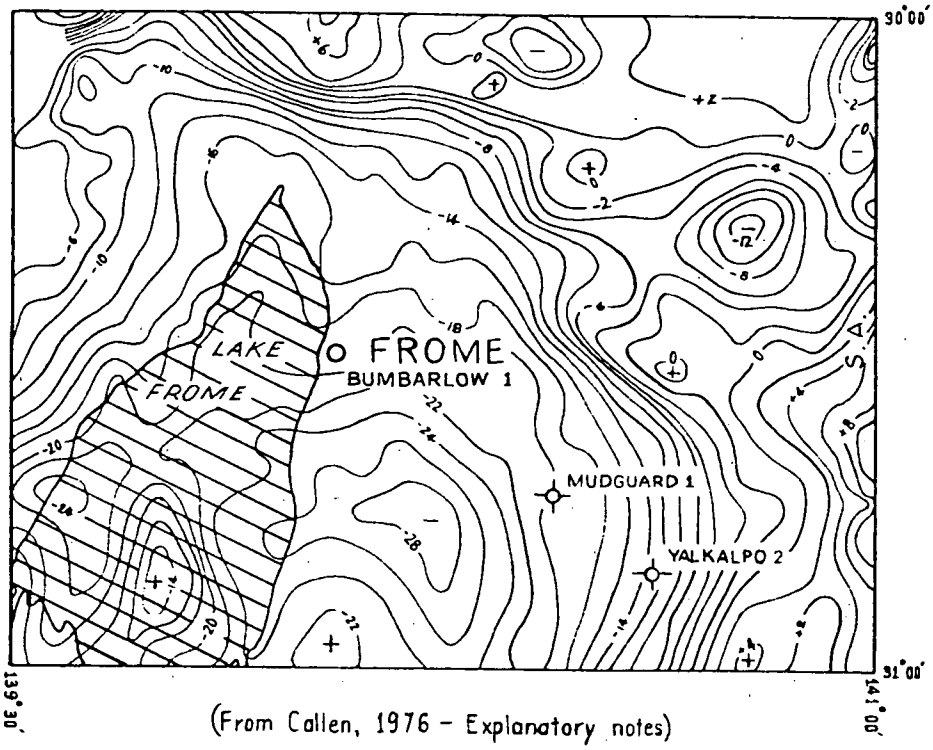
	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE 1:1,000,000
COMPILED B.C. Youngs	EAST ARROWIE BASIN	DATE 15-9-78
DRN K.W. CKD	ISOCHRONS OF TWO-WAY TIME TO TOP OF ?WIRREALPA LIMESTONE	PLAN NUMBER S13620



* See Fig. 2 for location of seismic line.

FIG. 3

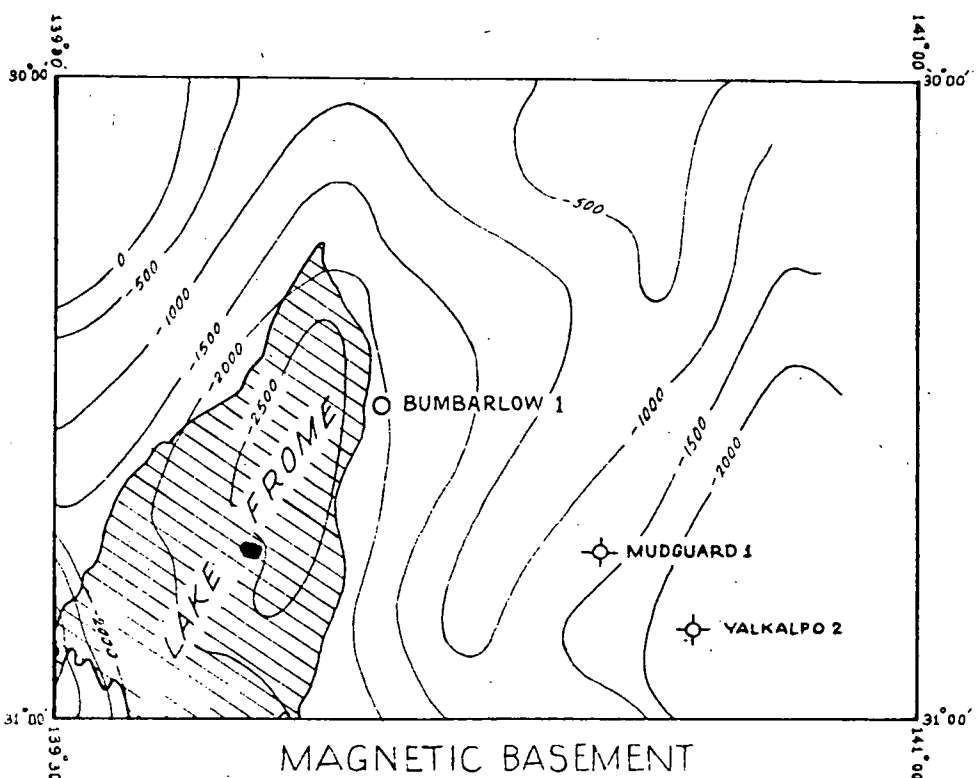
	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE:
COMPILED: B.C. Youngs	EAST ARROWIE BASIN	DATE: 15-9-78
DRN: K.W. CKD:	SEISMIC SECTION THROUGH BUMBARLOW 1 FROM LINE CFK, CRUSADER, 1971	PLAN NUMBER S13621



BOUGUER GRAVITY
(Contour Interval 2 milligals)

Compiled from plan drawn by CRUSADER OIL N.L. (Env. 1275 (v)
Data from surveys by B.M.R. and S.A. DEPT. of MINES

(From Callen, 1976 – Explanatory notes)



MAGNETIC BASEMENT
(Depths below Sea Level : Contour Interval 500m)

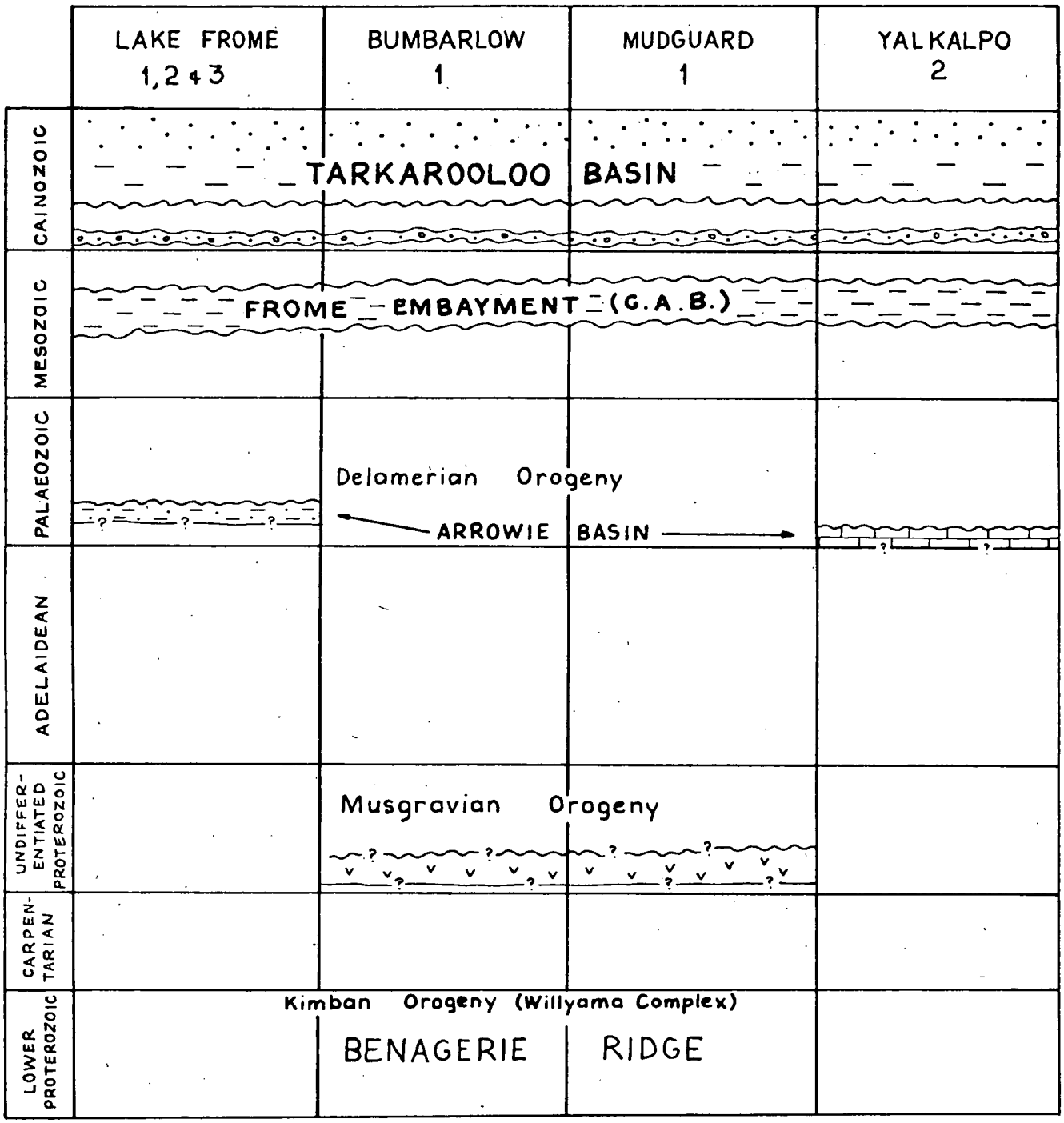
(From FROME Geological Sheet)

SCALE
0 50
KILOMETRES

FIG. 4

	DEPARTMENT OF MINES — SOUTH AUSTRALIA	Scale 1:1250 000 Approx
Compiled D.C. Youngs	EAST ARROWIE BASIN	Date : 15-9-78
Drn KW | Ckd	BOUGUER GRAVITY ANOMALIES AND DEPTHS TO MAGNETIC BASEMENT, FROME 1:250,000 Sheet	Drg No. S13622

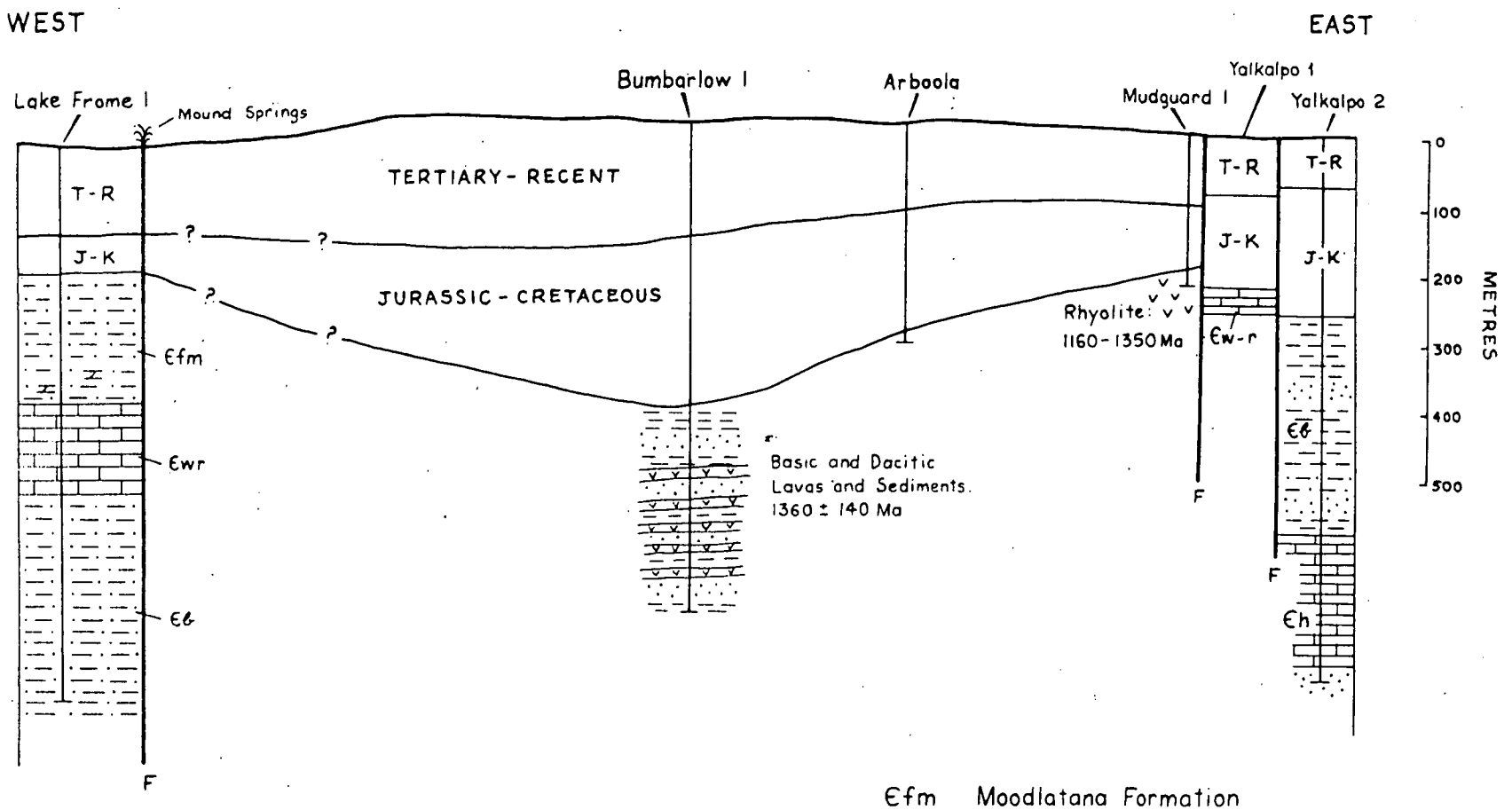
50—8.M F332



* See Fig. 1 for location of wells.

FIG. 5

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE
DRAWN B.C. Youngs	EAST ARROWIE BASIN	DATE 15-9-78
CHK. K.W.	SUMMARY OF STRATIGRAPHIC UNITS, TECTONIC EVENTS AND MAJOR OROGENIES	PLAN NUMBER S13623



$\frac{V}{H} = 80$

Efm Moodlatana Formation
Ew-r Wirrealpa Limestone
Eb Billy Creek Formation
Eh Hawker Group

* See Fig. 1 for location of section.

FIG. 6

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

EAST ARROWIE BASIN
GEOLOGICAL CROSS SECTION
LAKE FROME 1 TO YALKALPO 2

COMPILED: B.C Youngs
DRN: K.W.
CKD:

SCALE: H 1:800000
V 1:10000

DATE: 15-9-78

PLAN NUMBER
S13624

COMPOSITE WELL LOG

DEPARTMENT OF MINES AND ENERGY—SOUTH AUSTRALIA

BUMBARLOW No. 1 — 6937000SW00010

STATE : SOUTH AUSTRALIA

PETROLEUM TENEMENT: P.E.Ls 5 & 6 1 : 250000 MILE SHEET: FROME

WELL STATUS: DRY & ABANDONED

BASIN: GREAT ARTESIAN
ARROWIE/ADELAIDE
GEOSYNCLINE

LOCATION: 30° 29' 50" S, 140° 05' 15" E } s.p. 151, Crusader Line C.F.K.

ELEVATION: 31·146 m a.s.l. (all depths are from ground level, not K.B.)

DATE SPUDDED: 4-4-78

DATE DRILLING STOPPED: 13-6-78

DATE RIG RELEASED: 15-6-78

TOTAL DEPTH: 720·33 m (driller)

HOLE SIZE:

INCHES	FROM	TO
5¼"	Surface	410·00m
Core	408·95m	720·33m

CASING:

INCHES	DEPTH	CEMENTED TO	FROM
6"	18·54m		
3"	410·00m	Surface	

CEMENT PLUGS: 45m = 3 sacks
380m = 5 sacks

TYPE OF LOG	GAMMA RAY	NEUTRON	DENSITY	S.P.	P.R.	TEMPERATURE
DATE OF RUN	14-6-78	14-6-78	14-6-78	14-6-78	14-6-78	14-6-78
FIRST READING	724m	724m	724m	724m	724m	0m
LAST READING	0m	0m	400m	400m	400m	724m
INTERVAL MEASURED						
CASING LOGGER	409m	409m	409m	409m	409m	409m
CASING DRILLER	411m	411m	411m	411m	411m	411m
DEPTH REACHED	724m	724m	724m	724m	724m	724m
BOTTOM DRILLER	720m	720m	720m	720m	720m	720m
MUD TYPE						
DENSITY/VISCOSITY						
Ph/FLUID LOSS c.c.						
MUD RESISTIVITY						
RECORDED BY	A.W. Young	A.W. Young	A.W. Young	A.W. Young	A.W. Young	A.W. Young
WITNESSED BY						

OTHER SURVEYS: TYPE FROM TO
Caliper and Resistivity Logs were unable to be run owing to an obstruction at c. 430 metres

DRILLED BY: S.A. DEPARTMENT OF MINES & ENERGY

DRILLING METHOD: ROTARY AND CONTINUOUS WIRELINE DIAMOND CORING

LOGGED BY: S.A. DEPARTMENT OF MINES & ENERGY

LITHOLOGICAL REFERENCE

- Mudstone, clays
- Siltstone
- Sandstone, sands
- Conglomerate
- Shale
- Lava
- Gy Gypsiferous
- Dolomitic
- Conglomeratic
- Intraformational clasts
- Cross bedding
- T.S. Thin Section Sample Point

WELL SYMBOLS

- CORE INTERVAL AND NUMBER
- PLUGGED INTERVAL
- CASING SHOE
- FI FLUORESCENCE
- CUT WITH CCl_4

LITHOLOGY BY BRIDGET C YOUNGS
COMPILED BY BRIDGET C YOUNGS
DRAFTED BY KEVIN WILLCOX
DRAWING NUMBER:

FIG. 7

DEPARTMENT OF MINES — SOUTH AUSTRALIA

BUMBARLOW No. 1
COMPOSITE WELL LOG

PETROLEUM SECTION	B.C. YOUNGS GEOLOGIST	DRN K.W.	SCALE 1:500
		TCD	78-651
		CKD	
	SEN GEOLOGIST	EXD	DATE 15-9-78

BIT RECORD
DRILLING RATE
MINUTES / METRE
LITHOLOGY
TRACE
% OF CUTTINGS
HYDROCARBONS
LITHOLOGICAL DESCRIPTION
DEPTH (METRES)
GAMMA
S.P.
CORES (RECOVERIES & DIPS) PALAEONTOLOGY & PETROGRAPHY SAMPLES
LITHOLOGY
CASING, PLUGS & TESTS
DENSITY
NEUTRON
P.R.
STRATIGRAPHIC COLUMN
SAND, Medium brown, fine to medium grained subangular quartz grains.
CLAY, Medium brown, silty (some fine to medium quartz grains) Some gypsum, one millimetre plus. Sand increases towards base
CLAY, Predominantly dark brown-grey but red, brown, yellow streaks at top and becomes dark grey at 153 metres. Sticky, gypsiferous, white ? dolomite at 117 metres. Lignitic.
SAND, Grey and brown, partly consolidated, sub-rounded to sub-angular quartz grains, average 0·5 to 1 millimetre, rare 4 to 5 millimetre
CLAY, Grey-brown with white streaks, sticky. More indurated and with sub-rounded quartz pebbles at 260 metres and 360 metres. Becomes CLAYSTONE at 380 metres and contains quartz pebbles and ? ironstone fragments. CONGLOMERATE below 394 metres, pink, yellow, white quartz and sandstone fragments (c 36 millimetres), red and green mudstone fragments at base
SILTSTONE and MUDSTONE, Green-grey and maroon, (laminated - thinly bedded to 419m)
SANDSTONE and CONGLOMERATE; With rare MUDSTONE laminations. Maroon, some green-grey. Conglomeratic fragments are quartz, metasediments and ? volcanics. Cyclic sedimentation conglomerates → sandstones. Mudstone increases downwards, some intraformational clasts, flaser bedding in places
CONGLOMERATE, Quartz and argillaceous sediment/metasediment fragments
LAVAS, Predominantly basalts and dacites, highly altered and vesicular at the tops of flows. Interbedded with MUDSTONES, SILTSTONES and SANDSTONES - predominantly maroon to cream, flat-bedded, some lithic fragments. Very little evidence of altered zones between lavas and sediments.
Samples from c 645 metres were used in Rb-Sr dating.
SHALE, Dark grey-black, with very fine buff laminations. Dolomitic, ? cleavage ≈ 30° to 40° in places
? COONARBINE + EURINILLA FMS
? RECENT - QUATERNARY
NAMBA FORMATION
MIOCENE
EYRE FORMATION
PALEOCENE-EOCENE
MARREE FORMATION
? JURASSIC — CRETACEOUS
CADNA-OWIE FORMATION
UN-NAMED
PROTEROZOIC