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REPORT BOOK 96/31

BIG LAKE SUITE NOT TIRRAWARRA SANDSTONE IN THE MOOMBA FIELD, COOPER BASIN, SA

by

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Granodiorite core recovered from Moomba 72 has led to the recognition of an altered zone at the top of pre-Permian 'basement'. The altered zone has been previously misinterpreted as Early Permian Tirrawarra Sandstone. Consequently, the equivalent of a third of a well for the Moomba field has been drilled into 'basement'. In addition, 15 drill stem tests were effectively wasted, testing 'basement'.

The assumption that 'Tirrawarra Sandstone' (occasionally informally termed 'Tirrawarra conglomerate') did exist in the Moomba Field was inspired by the presence of a conglomeratic facies at the top of the Tirrawarra Sandstone, in the Big Lake field. Both the altered granodiorite and the conglomerate display elevated gamma-ray values which exceed 200 API.

The alteration zone recognised in granitoids of the Carboniferous Big Lake Suite is similarly found in Warburton Basin lithologies subcropping beneath the Cooper Basin. The significance or nature of this zone is currently unknown. However, in Lycosa 1, this zone appears to act as a seal for deeper Dullingari Group reservoirs.

INTRODUCTION

The Moomba field in the central Cooper Basin, South Australia produces a significant volume of gas from several formations (Toolachee, Daralingie, Epsilon, Patchawarra). Elsewhere in the basin, the Tirrawarra Sandstone is a significant reservoir for both oil and gas. The interpretation that 'Tirrawarra Sandstone' may also be present in the Moomba field provided a significant play. This work shows how the putative Tirrawarra Sandstone in the Moomba Field has been misinterpreted, how inconclusive data led to these interpretations, and examines the significance of the revised interpretation.

TIRRAWARRA SANDSTONE CONGLOMERATE FACIES

The 'Tirrawarra Conglomerate' (Stanley & Halliday 1984, Steveson & Gravestock 1984) is recognised by its a high-gamma ray wireline log response, typically off scale (>200 API). The conglomerate occurs beneath the Patchawarra Formation and above the Tirrawarra Sandstone (sensu stricto) (Fig. 1). Plutonic quartz, occasional highly altered feldspars and altered micas indicate a granitic source for the conglomerate. The presence of zircon, monazite and apatite (Stanley and Halliday 1984) further indicates a granitic source. The high thorium on gamma-ray spectroscopy (NGS) logs (Steveson & Gravestock 1984) is presumably from the radioactive decay of uranium in the granites and responsible for the elevated gamma-ray values.

The conglomerate is typically a 'hotting' upwards sequence and occurs in 21 of the 23 deep Permian wells in the Big Lake field as well as in Moomba 69. A total of 500 m of conglomeratic facies has been intersected in the Big Lake field, where it attains a maximum thickness of 63 m.

BIG LAKE SUITE

The Big Lake Suite (Gatehouse *et al*., 1995) of granodiorite is recognised from elevated gamma-ray responses in logs (typically >200 API) for 'basement' sections beneath the central Cooper Basin. These granitiods contain greatly elevated concentrations of uranium, up to 40 ppm. Such concentrations exceed values recorded in Australia for granitoids of similar age (Fig. 2) and are responsible for the high gamma-ray values (Fig. 3).

Thirty four wells are interpreted to have intersected the Big Lake Suite beneath the Cooper Basin (Fig. 4). The majority of these interpretations was based on high gamma-ray values in logs. Inspection of cuttings or cores were then made to confirm these observations.

In addition to high gamma-ray values, unaltered Big Lake Suite displays distinct log characteristics (Fig. 3). Several logs indicate good hole conditions which would be expected in homogeneous, solid basement. These includes an in-gauge and uniform caliper; high resistivity values (on the deeper reading tools) with no separation indicating no invasion and a poorly conducting lithology; and sonic logs with a uniform, fast transit time (<60 μs/ft). Values on neutron logs are typically close to zero and density is approximately 2.60 gm/cm^3. Therefore, the Neutron\Density crossover typically appears like that of a quartz cemented sandstone.

A CASE OF MISTAKEN IDENTITY: NOT THE TIRRAWARRA SANDSTONE

Well completion reports from Moomba field interpret 19 of the 30 deep Permian wells to have intersected the 'Tirrawarra Sandstone'. A total of 894 m of interpreted 'Tirrawarra Sandstone' has been drilled with a maximum intersection of 115 m. The presence of the Tirrawarra Sandstone was first proposed in Moomba 26, interpreted as a fine to medium grained, white, clear, fairly sorted, angular sandstone. Since Moomba 26, 18 wells attained total depth in the Big Lake Suite. Of these, 16 were interpreted to contain 'Tirrawarra Sandstone'. Of the remaining 2 wells, Moomba 58 interpreted granite wash rather than 'Tirrawarra Sandstone' and Moomba 59 was interpreted to have drilled though the Patchawarra directly into granitic basement. Only Moomba 55, interpreted 'Tirrawarra Sandstone' (7.5 m) on non-granitic basement and Moomba 69 contains Tirrawarra Sandstone (sensu stricto) off the flank of the Moomba structure. Of the remaining three wells which reached a non-granitic 'basement', none was interpreted to have intersected 'Tirrawarra Sandstone'.

The 'Tirrawarra Sandstone' is interpreted as an high gamma-ray sandstone (Figs. 3,5), as found in the Big Lake Field. However, in the Moomba Field, the 'Tirrawarra Sandstone' unconformably lies on 'basement' (no Merrimelia facies have been recognised), whereas in the Big Lake Field, the high gamma-ray conglomeratic facies overlies Tirrawarra Sandstone (sensu stricto) (Fig. 1). Resistivity logs indicate invasion, however, the 'sandstone' appears tight and low resistivity values indicate saline waters rather than hydrocarbons.

Neutron\Density crossovers do appear as sandstone.

Ten wells drilled since Moomba 26 have targeted the 'Tirrawarra Sandstone' as a primary or secondary objective. A total of 15 drill stem tests have been conducted in 'basement' beneath the Cooper Basin. All were quoted to have flowed gas at a rate too small to measure except for tests which overlapped the Patchawarra Formation. Moomba 72, with a primary target of 'Tirrawarra Sandstone' gas, cored the upper part of the interpreted 'sandstone' to ascertain true porosity, permeability and mineralogy. Despite core/log analysis indicating a tight shaley reservoir with core permeability at a maximum 5 millidarcies, all four subsequently drilled deep Permian Moomba wells either prognosed or interpreted a 'Tirrawarra Sandstone' intersection.

Despite core descriptions suggesting otherwise, core from Moomba 72 recovered 13.5 m of altered granodiorite (Fig. 5). The log characteristics for this zone do not appear the same as that for fresh granodiorite described earlier. Indeed, all interpreted 'Tirrawarra Sandstone' occurring above the Big Lake Suite in the Moomba Field displays the same log characteristics as that for an altered granodiorite. It can therefore be concluded that no 'Tirrawarra Sandstone' exists in the Moomba Field. The Big Lake Suite is characterised on logs only by high Gamma-Ray values. Other described log features represent altered and/or unaltered zones. Table 1 lists formations and depths to altered/unaltered 'basement' for the Moomba field.

Given that a significant sonic shift occurs at the base of the altered zone, it is likely that a seismic reflector will exist. With intersections of the altered zone up to 92 m (Moomba 77), this zone can and has be interpreted within seismic sections (Fig. 6).

TECTONIC IMPLICATIONS

U-Pb zircon isotopic analysis established the age of the Big Lake Suite to be 298±4 and 323±5 Ma (Gatehouse *et al.*, 1995). These granitoids were subsequently exposed at the surface prior to or during initial Cooper Basin sedimentation. Prehnite in Mooracoochie Volcanics, Gidgealpa 5, indicate that burial metamorphism up to 8 km occurred. It is possible that the Big Lake Suite was emplaced at an equivalent depth (Boucher 1994). If sediments of Tirrawarra Sandstone age (280-274 Ma) were to exist in the Moomba field, then up to 8 km of Warburton Basin sediments would need to be removed in 18 million years. This compares to just over 3 km of subsidence and sedimentation in 270 Million years since. Given that the 'Tirrawarra Sandstone' does not occur in the Moomba Field and Middle Patchawarra sediments overlie 'basement', and extra 10 million years is allowed for removal of sediments overlying the Big Lake Suite. In the Big Lake Field, however, the Merrimelia Formation overlies the Big Lake Suite. Therefore, the Warburton Basin sediments overlying the granitoids were removed rapidly prior to Merrimelia Formation time (285-277 Ma).

Apak (1994) assumed unconformities removed the conglomeratic facies of the Tirrawarra Sandstone and lower units of the Patchawarra Formation in the Moomba area. This required episodic rejuvenation of basement structures. Yet basement 'structures' are more likely to be the topographic expression of a buried granitic landscape. Sediments tend to thin and lap onto basement highs rather than appear structurally controlled. The Moomba area can therefore be considered as an residual topographic high during early Cooper Basin sedimentation. At times, erosion off this high produced granitic sands (e.g.

conglomeratic facies of the Tirrawarra Sandstone, Big Lake field and Moomba 69). Such facies would therefore be expected around the entire Moomba 'structure'. Eventually, sediments onlapped and completely covered the Moomba topographic high, with 'basement' in Moomba 2 the last to be covered.

CONCLUSION

The Tirrawarra Sandstone does not exist in the Moomba field. The high-gamma ray zones on logs interpreted to be Tirrawarra Sandstone are granodiorite of the Big Lake Suite. Within the Big Lake Suite, two distinct zones appear. The upper zone, subcropping beneath the Cooper Basin, is altered and displays sonic, resistivity, porosity and density characteristics which differ from fresh granodiorite. This change in rock property similarly effects seismic; where an additional reflector occurs within the granite at the boundary between the fresh and altered zones.

By interpreting the altered zone within the Big Lake Suite as unproductive Tirrawarra Sandstone, a great deal of expenditure has been wasted. In addition the prospectively of the Early Permian in the Moomba area is downgraded.

A better understanding of the altered zone will facilitate recognition of the top of 'basement' as distinct from Cooper Basin sediments. An understanding of this zone may prove to be tectonically and economically significant, beyond the confines of the Moomba and Big Lake fields.

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WELL	BASEMENT UNIT	TOP ALTERED ZONE (ft)	TOP UNALTERED ZONE (ft)	THICK (ft)	TOP ALTERED ZONE (m)	TOP UNALTERED ZONE (m)	THICK (m)
MOOMBA 1	BIG LAKE SUITE	9320	9446	126	2840.74	2879.14	38.40
MOOMBA 2	DULLINGARI GP	8765	9030	265	2671.57	2752.34	80.77
MOOMBA 3	Pando Fm		9443	0		2878.23	0
MOOMBA 7	Pando Fm		9716	0		2961.44	0
MOOMBA 8	BIG LAKE SUITE	9062	*	30+	2762.10	*	9.14+
MOOMBA 26	BIG LAKE SUITE	9413	9521	108	2869.08	2902.00	32.92
MOOMBA 27	BIG LAKE SUITE	9778	9980	202	2980.33	3041.90	61.87
MOOMBA 50	BIG LAKE SUITE	9828	9888	60	2995.57	3013.86	18.29
MOOMBA 51	BIG LAKE SUITE	10942	10972	30	3335.12	3344.27	9.14
MOOMBA 54	BIG LAKE SUITE	9714	9747	33	2960.83	2970.89	10.06
MOOMBA 55	Innamincka Fm		10115	0		3083.05	0
MOOMBA 56	BIG LAKE SUITE	10146	10340	194	3092.50	3151.63	59.13
MOOMBA 57	BIG LAKE SUITE	10042	10286	244	3060.80	3135.17	74.37
MOOMBA 58	BIG LAKE SUITE	9884	10065	181	3012.64	3067.81	55.17
MOOMBA 59	BIG LAKE SUITE	9362	*	50+	2853.54	*	15.24+
MOOMBA 60	BIG LAKE SUITE	10250	10538	288	3124.20	3211.98	87.78
MOOMBA 61	BIG LAKE SUITE	10526	10696	170	3208.32	3260.14	51.82
MOOMBA 62	Innamincka Fm	9376	9661	285	2857.80	2944.67	86.87
MOOMBA 62	BIG LAKE SUITE	9603	A.A.		2926.99	A.A.	
MOOMBA 63	BIG LAKE SUITE	9461	9517	56	2883.71	2900.78	17.07
MOOMBA 66	BIG LAKE SUITE	10059	10302	243	3065.98	3140.05	74.07
MOOMBA 69	Pando Fm	10638	10688	50	3242.46	3257.70	15.24
MOOMBA 70	BIG LAKE SUITE	10350	*	200+	3154.68	*	60.96+
MOOMBA 72	BIG LAKE SUITE	9855	9931	76	3003.80	3026.97	23.16
MOOMBA 73	BIG LAKE SUITE	9875	9940	65	3009.90	3029.71	19.81
MOOMBA 74	BIG LAKE SUITE	10035	10064	29	3058.67	3067.51	8.84
MOOMBA 75	Pando Fm		10160	0		3096.77	0
MOOMBA 77	BIG LAKE SUITE	9736	10037	301	2967.53	3059.28	91.74
MOOMBA NORTH 1	BIG LAKE SUITE	9830	9904	74	2996.18	3018.74	22.56
MOOMBA NORTH 2	Innamincka Fm		9670	0		2947.42	0
MOOMBA SOUTH 1	Pando Fm	9843	9990	147	3000.15	3044.95	44.81
MOOMBA SOUTH 1	BIG LAKE SUITE		10166			3098.60	

Table 1. Moomba field, 'basement' units, depths to top of altered\unaltered zones (*=Not Penetrated).

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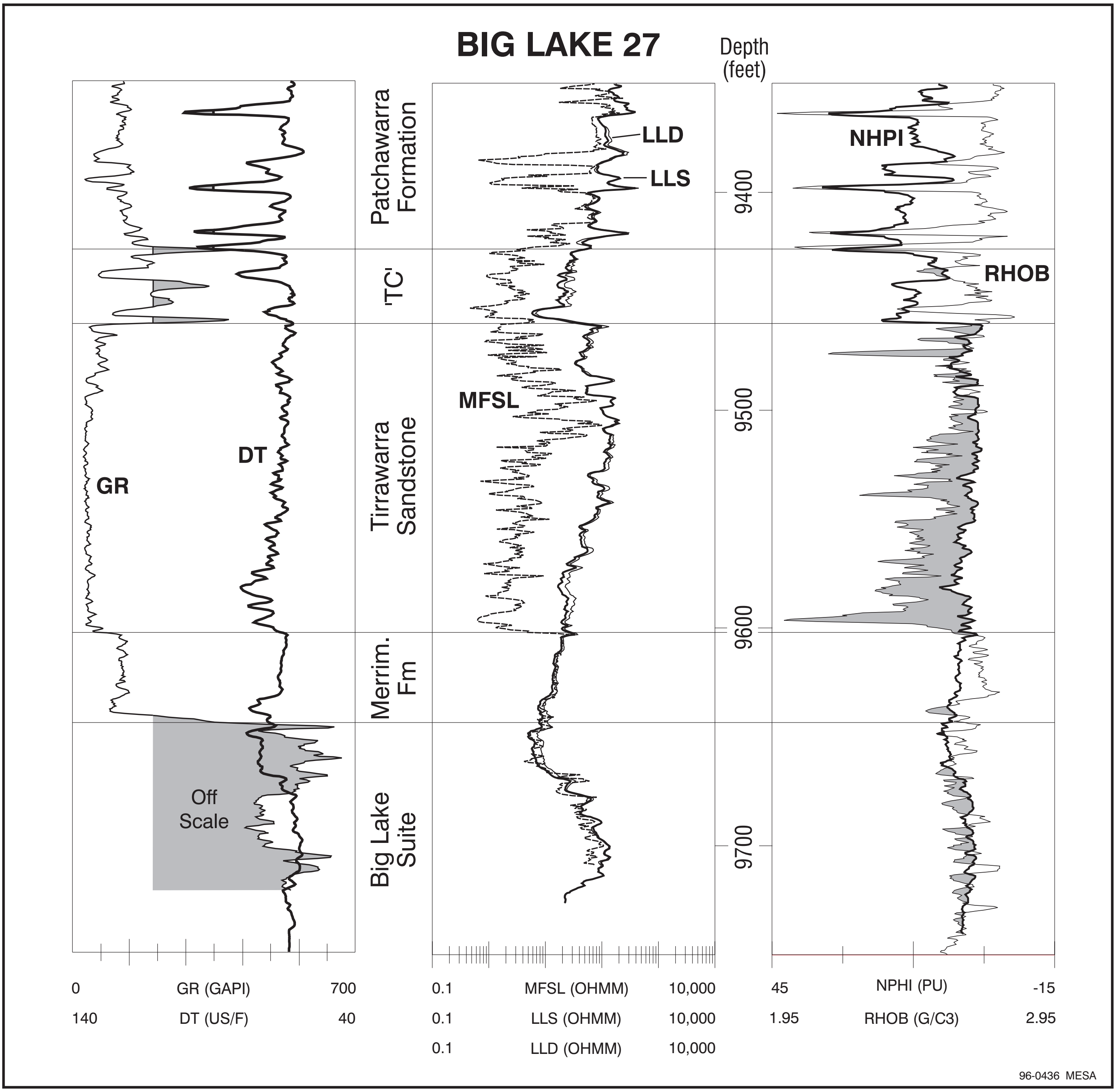

Figure 1. *Basal Cooper Basin and Big Lake Suite log signatures, Big Lake 27. The 'Tirrawarra Conglomerate' ('TC') is a high gamma-ray sedimentary facies of granitic provenance. Note gamma-ray scale is 0-700 API.*

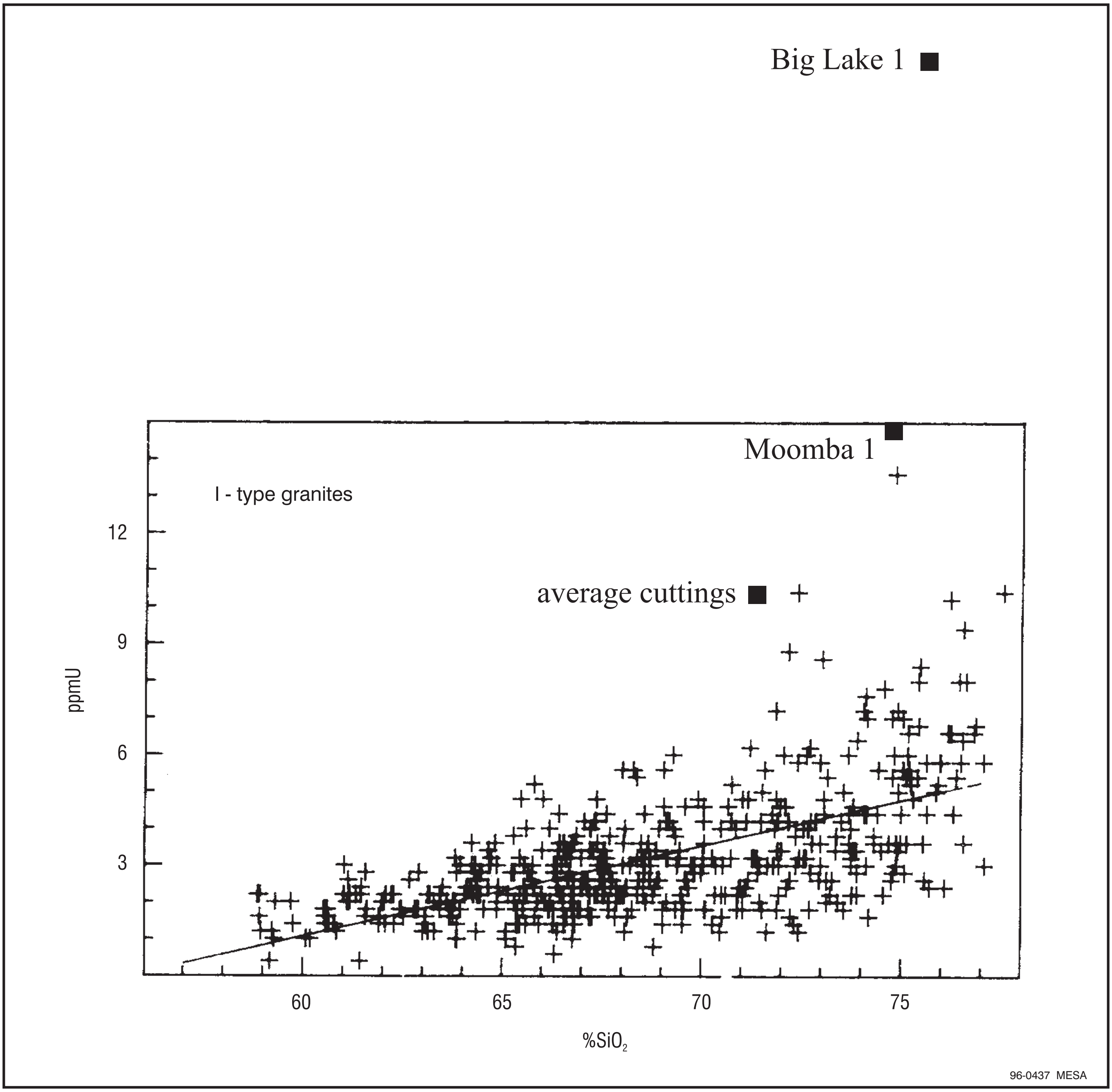

Figure 2. *Uranium content of granitoids from the Lachlan Fold Belt of Palaeozoic age (after Sawka and Chappell 1986) and the Big Lake Suite. Averaged values for cuttings are likely to be diluted by contamination from material up the hole. Consequent to high uranium values, granitoids or granitoid sourced sediments will display high gamma-ray responses on logs.*

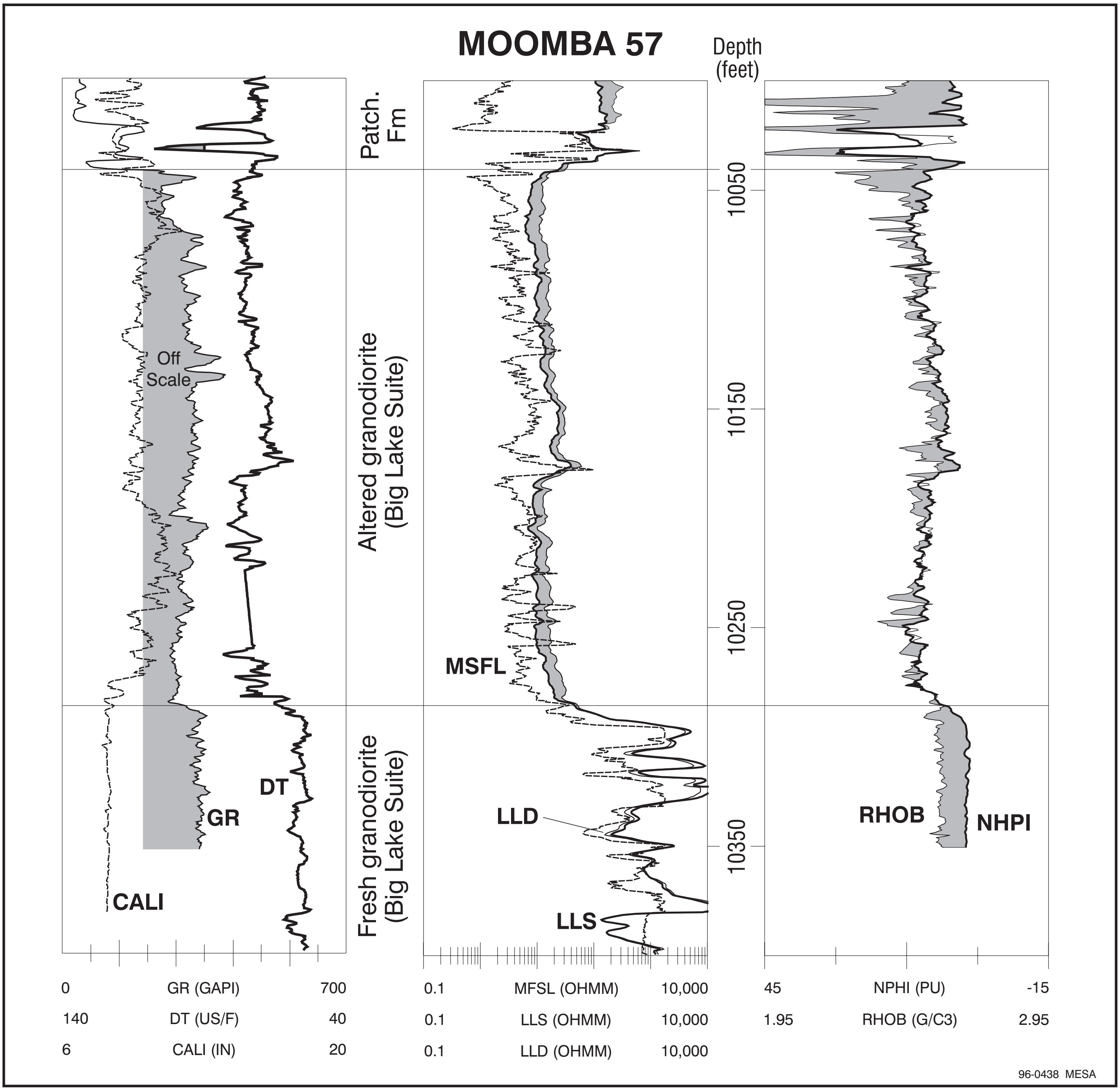

Figure 3. *Example of log signatures for the Big Lake Suite and associated altered zone which had previously been considered to be the Tirrawarra Sandstone. See text for details.*

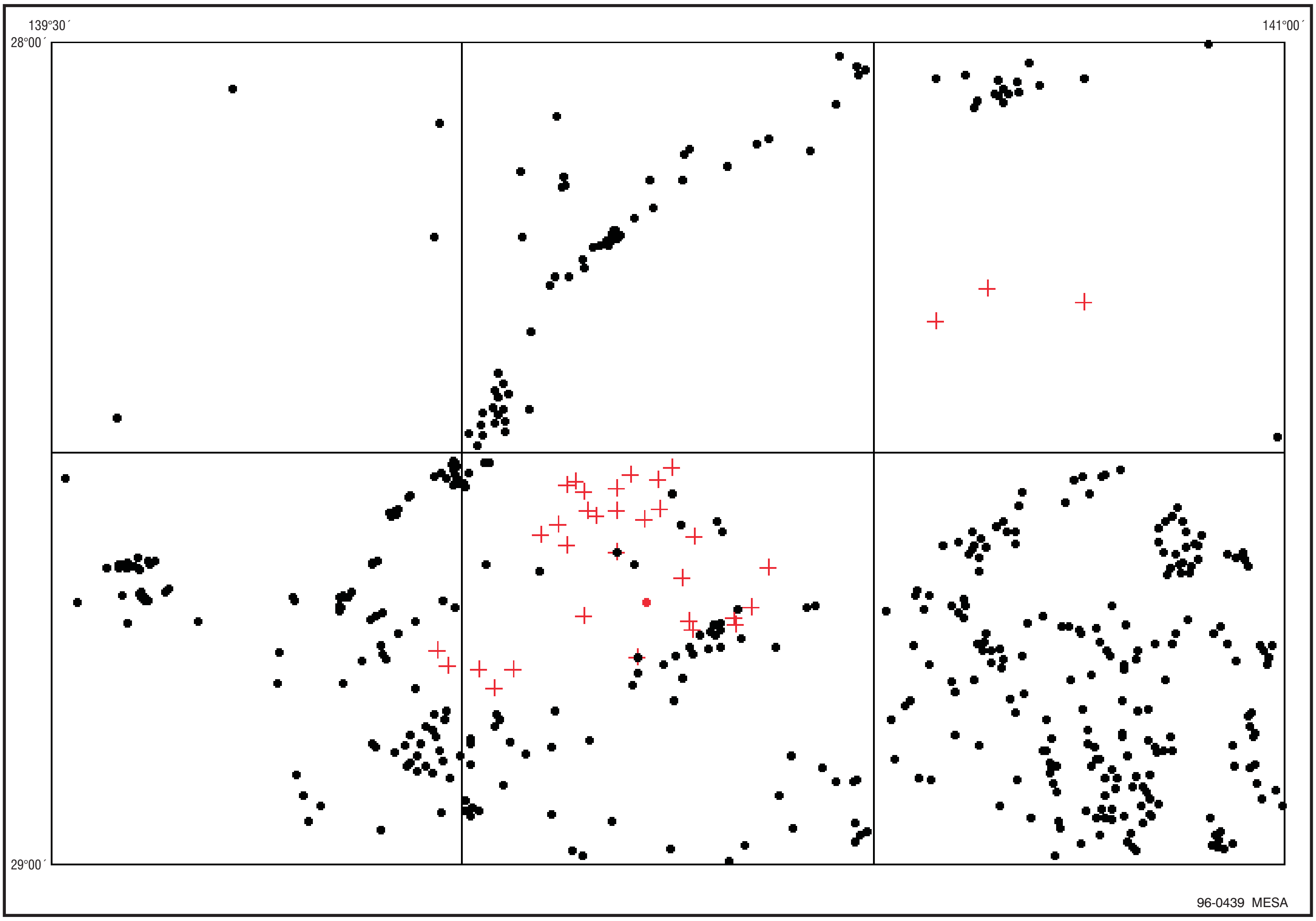

Figure 4. *Location of wells containing granitoids (+) and non-granitic (•) lithologies subcropping beneath the central Cooper and Eromanga Basins.*

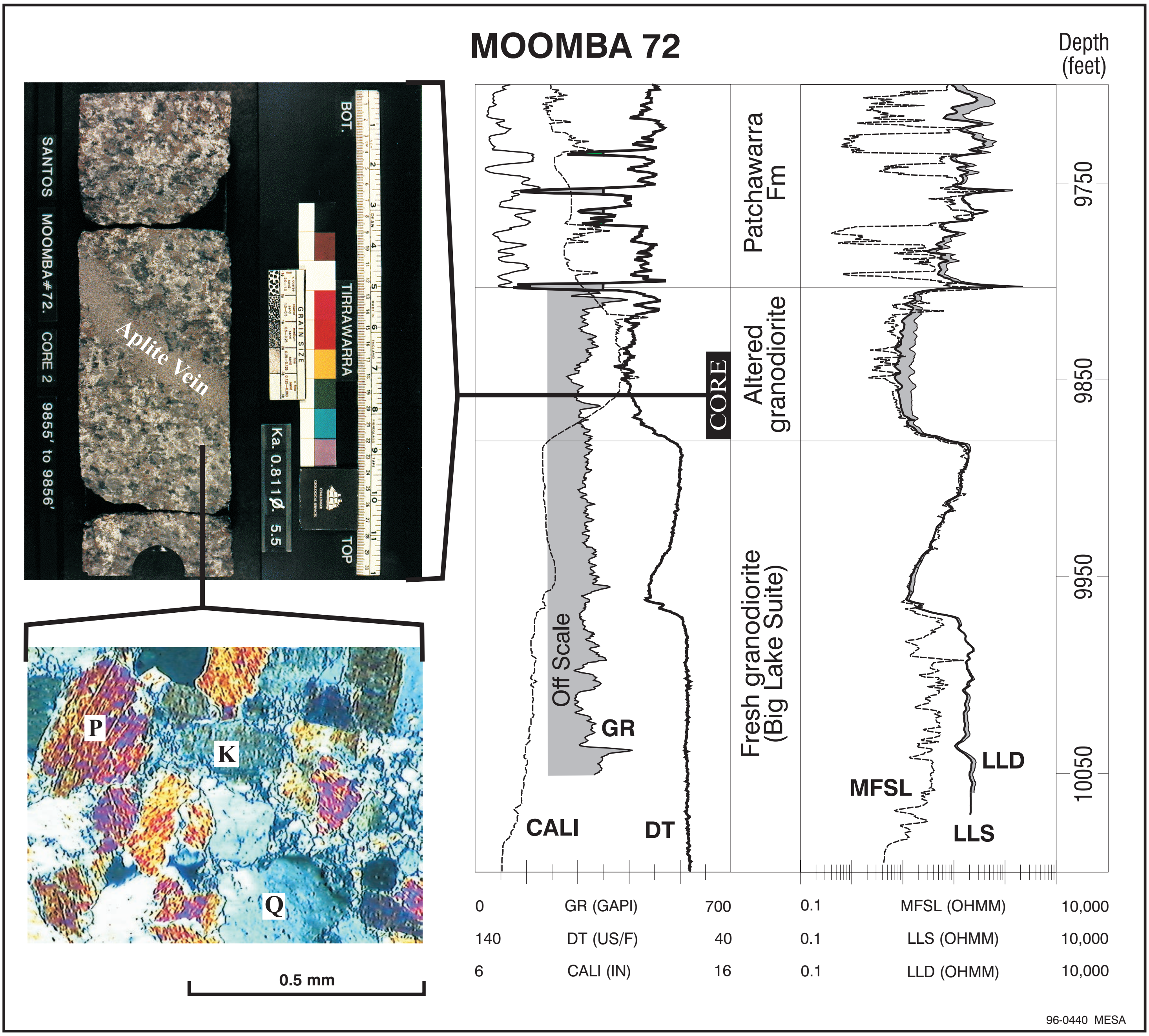

Figure 5. *Core photo and thin section from part of granodiorite core from Moomba 72. This core was taken from the altered zone, subcropping, beneath the Cooper Basin previously considered to be Tirrawarra Sandstone. The core shown is crossed by an aplite vein. Igneous textures are preserved in the thin section, mineralogy includes quartz (Q), sericitized plagioclase (P) and altered potassic feldspars (K).*

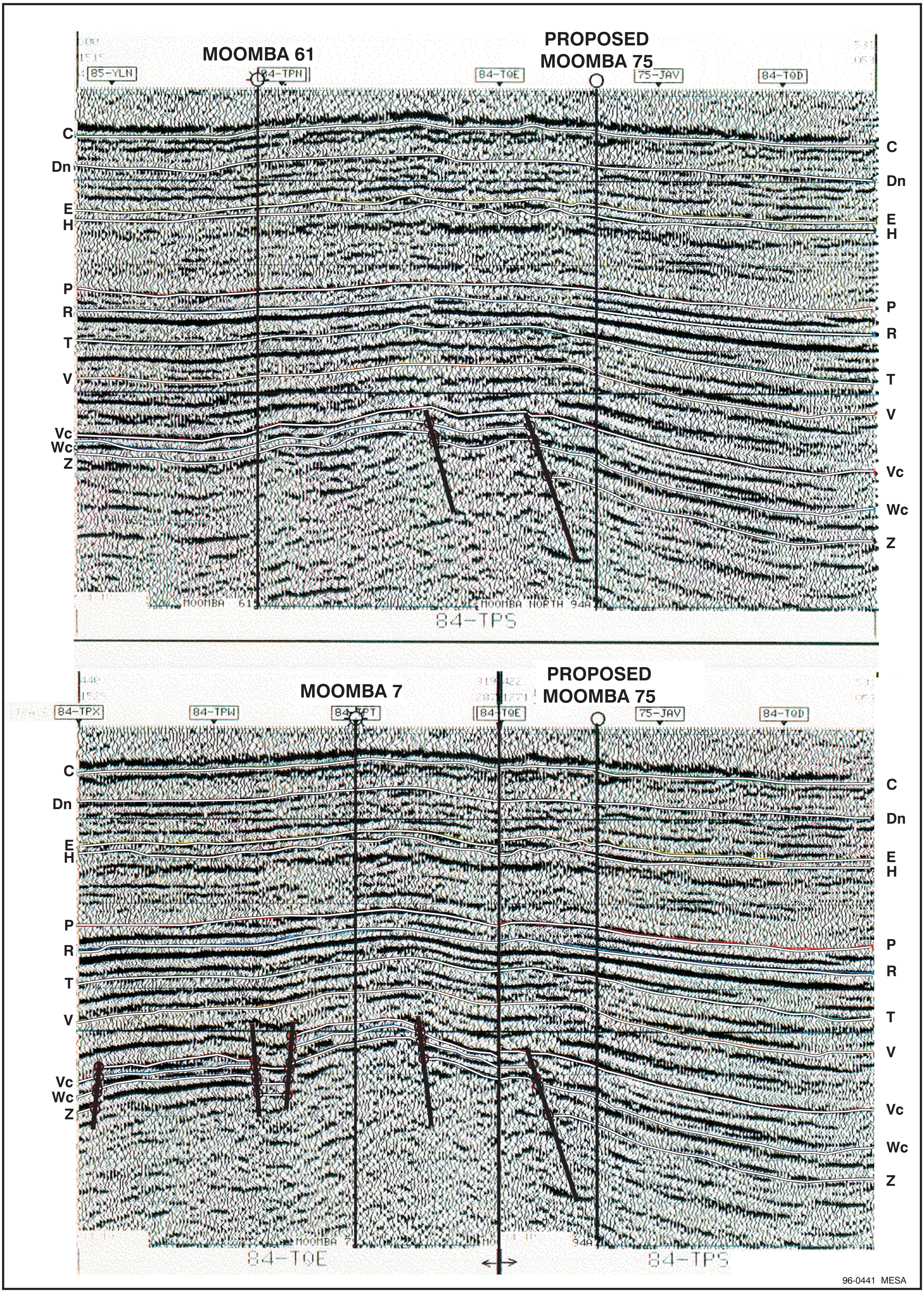

Figure 6. Examples of interpretations of 'Tirrawarra Sandstone' (Wc-Z). From Moomba 75 well proposal.