Chapter 4

Eumeralla Formation Facies and Distribution

4. EUMERALLA FORMATION FACIES

4.1 Previous Work

The Eumeralla Formation thickens in a broad wedge towards its main depocentre in the southwestern Otway Basin, where the base of the formation occurs at a depth of over 5000 meters (Figs 4.1, 4.2). The formation is up to ~1500m thick in the Penola Trough and more than 2500m thick in Geltwood Beach-1 (Morton et al. 1995).

Montague (1989) subdivided the Eumeralla Formation into five units (I to V) based on log character and palynology of a South Australian data set. Tupper et al. (1993) proposed a subdivision into two units, upper and lower, with the boundary corresponding to the base of the *C. striatus* palynological zone. Units V and IV of Montague (1989) correspond to the lower Eumeralla Formation of Tupper et al. (1993), Units III to I correspond to the upper Eumeralla. Montague (1989) suggested that the formation could be divided into two groups based on mineralogy. The upper Eumeralla Formation has a lithic nature and contains a significantly larger amount of plagioclase and chlorite due to active volcanism during deposition, whereas the lower Eumeralla is quartz rich from reworking of Crayfish Group sediments (Montague 1989). Struckmeyer and Felton (1990) recognized an upper and lower Eumeralla Formation based on the boundary between the lower and upper *C. paradoxa* zone and a change from silty to sandy lithology in Victorian outcrops. A division into upper, middle and lower Eumeralla Formations of a Eumeralla Group by Kopsen and Scholefield (1990) is generally not accepted by industry, as it is not based on unique lithological criteria (Morton et al. 1995). A new subdivision was proposed by Boult (1996) and Boult et al. (2002) after work on a data set comprising both Victorian and South Australian wells. This subdivision is based on Montague (1989), but includes a Unit VI towards the base of the formation.

The Heathfield Sandstone Member refers to a mid-Eumeralla Formation sandstone in Heathfield-1 deposited as thin channel and crevasse-splay sands (Morton et al. 1995). Morton et al. (1994, 1995) suggested that the name Heathfield Sandstone Member should be avoided as the sandstone has not been defined formally and cannot be confidently correlated between wells. The term will not be used in this study. In the following facies descriptions, the Windermere Sandstone Member at the base of the Eumeralla as well as Eumeralla Formation

Units VI to I will be addressed. Sedimentary structures described within Units I and IV are taken from Montague (1989) as these intervals were not investigated during this study.

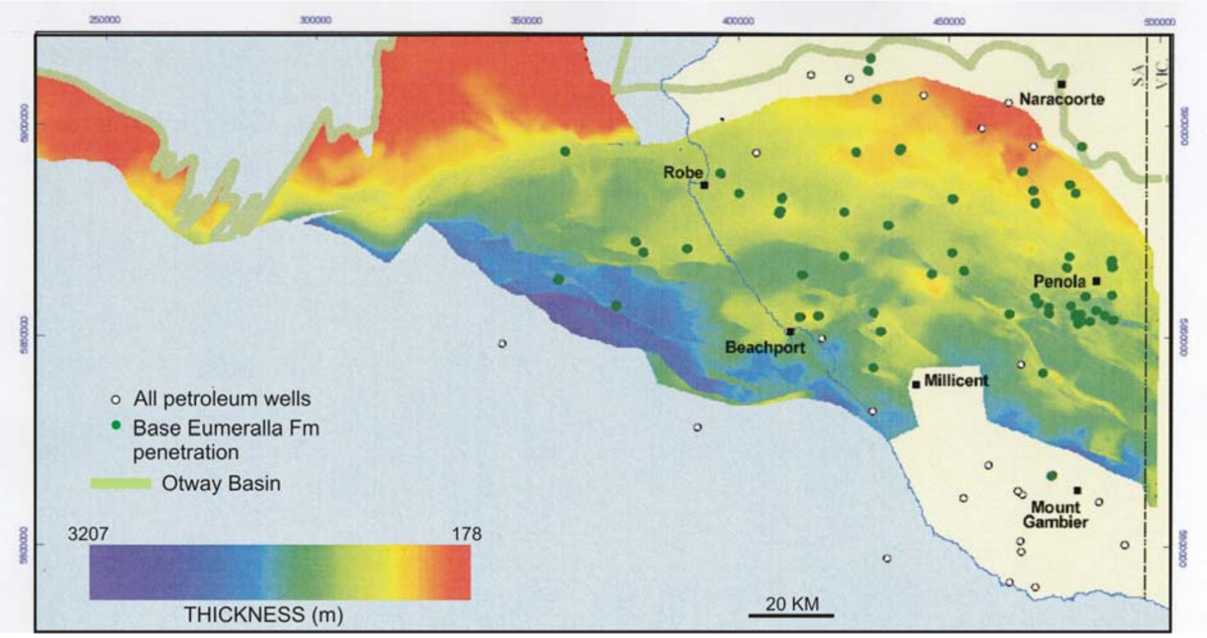

Figure 4.1 Eumeralla Formation isopach map. Modified from Jensen-Schmidt et al. (2002).

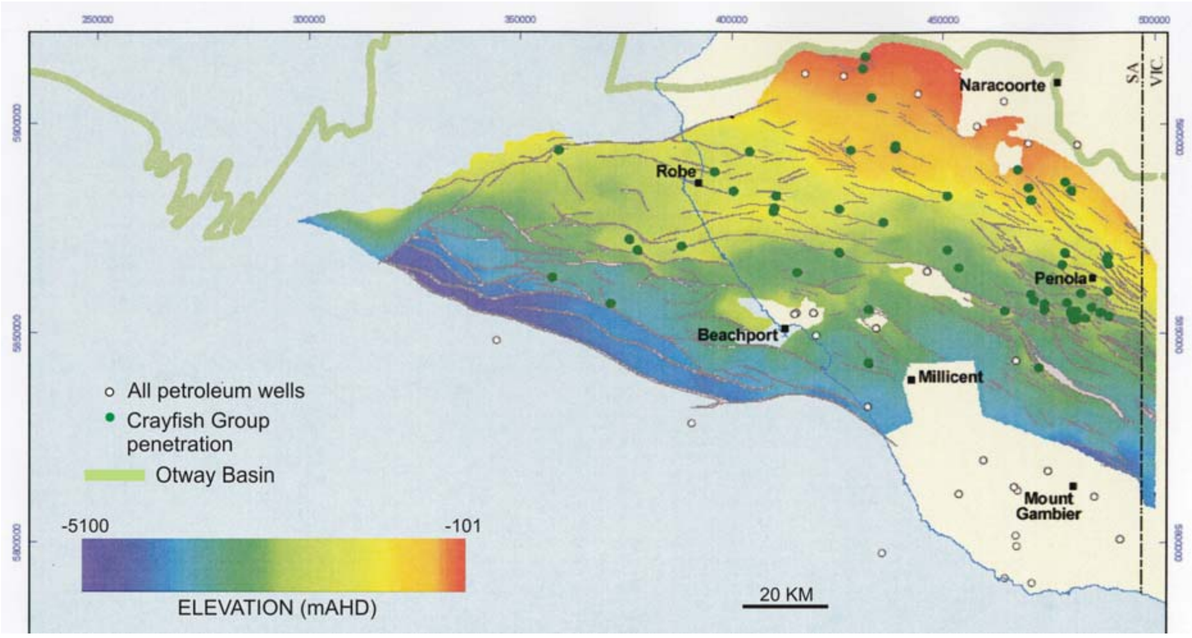

Figure 4.2 Depth to top Crayfish Group. Modified from Jensen-Schmidt et al. (2002).

4.2 The Crayfish Unconformity

The placement of the Crayfish Unconformity is debatable as it commonly occurs between the Katnook Sandstone and the Windermere Sandstone Member, two very similar sandstones. Some authors (Beaumont-Smith 1994, Price 2000) have suggested that these may in fact be the same sandstone, and that the placement of the unconformity needs to be reassessed. The Katnook Sandstone is absent in several areas due to erosion and facies change (Morton et al. 1995). In the Penola Trough, the sandstone varies in thickness from 77 meters in the Katnook region to 683 metres in Crankshaft-1 (Morton et al. 1995). The Windermere Sandstone Member is more widespread with thicknesses ranging from 1 to 160 metres (Morton et al. 1995). Frequent, excellent palynological markers indicate that the unconformity is located at the base of the *P. notensis* Zone (Morgan et al. 1995). Price (2000), however, noted that the *P. notensis* zone extends down into the top of the Katnook Sandstone in Katnook-2 (Penola Trough), and argues that the Eumeralla – Crayfish Group sediments are close to conformable in this well.

The work conducted on the Crayfish unconformity, as part of this study, suggests that the unconformity separates the two sandstones into two separate intervals. The Windermere Sandstone Member can clearly be seen on seismic sections to overlie an angular unconformity, whereas the Katnook Sandstone is part of the underlying Crayfish Group with sediments thickening within half grabens below the unconformity (Figs 4.3, 4.4).

4.3 Windermere Sandstone Member

Description

The Windermere Sandstone Member is highly variable across the basin. The grain sizes in core and cuttings from different wells range from siltstones through fine-grained sandstones to coarse and pebbly sandstones. The sediments are poorly to well sorted, and occur both as relatively well-rounded quartz-dominated coarse sandstone and sub-rounded pebbly feldspar-rich sandstone (Figs 4.5, 4.6). The sandstone is commonly massive with no distinctive sedimentary structures developed. Water-escape structures and ripple cross bedding occur in core from the Penola Trough (Morton et al. 1995). Planar cross bedding is present within some intervals. Organic material and very thin coal beds are present in core. The Windermere Sandstone has a low and constant gamma ray log response, which is distinctly different from the overlying Eumeralla intervals (Fig. 4.7a, b, c). The SP log signature is more variable both vertically and between different wells (Fig. 4.7). The Windermere Sandstone is commonly

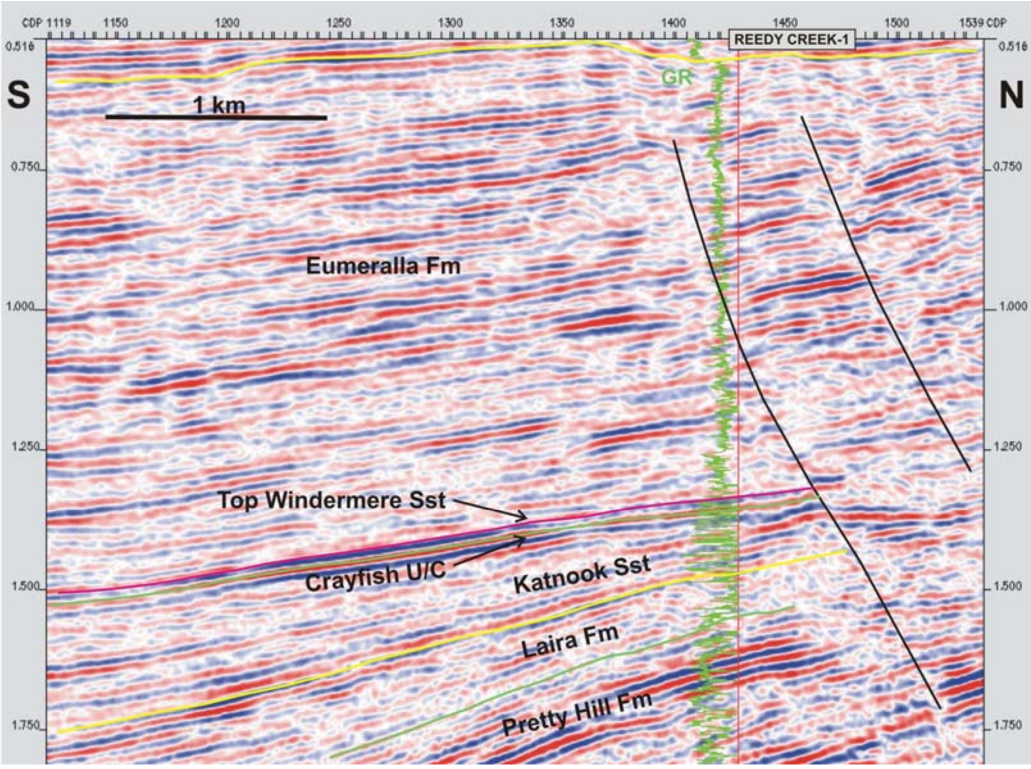

Figure 4.3 The Crayfish Unconformity separates the Katnook Sandstone from the overlying Windermere Sandstone Member of the Eumeralla Formation on seismic line sc90-15. The location of the seismic line is shown in figure 4.4.

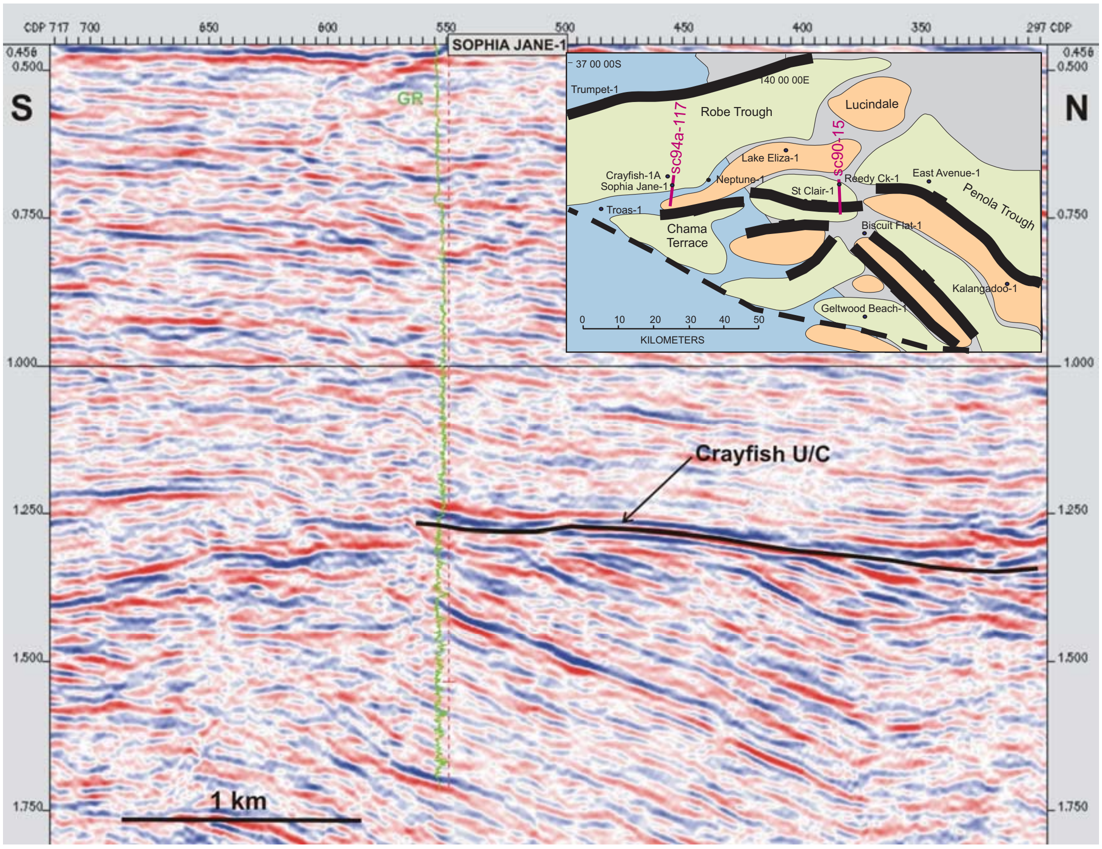

Figure 4.4 The Crayfish Group sediments thicken within half grabens below the Crayfish unconformity as seen on seismic line sc94a-117.

Figure 4.5 Photos from Windermere Sandstone Member cuttings showing its different character in two Otway Basin wells. A relatively well-sorted and well-rounded quartz-dominated coarse sandstone dominate in Trumpet-1 (top). In Diamond Swamp-1 (bottom), the Windermere consists of poorly sorted, sub-rounded pebbly feldspar-rich sandstone. Well locations are shown in Figure 4.6.

associated with the *P. notensis* palynological zone.

Quartz and feldspar are the dominant minerals in a sample analysed from Mocamboro-11 (Fig. 4.8). The sediments are moderately sorted, and the grain size varies from fine to medium sand (Fig. 4.8). A clay-dominated matrix and authigenic clays that rim framework grains reduce primary porosity (Figs 4.8, 4.9). Secondary porosity has developed from dissolution of feldspar. Kaolinite booklets occur as pore-filling clay (Figs 4.8, 4.9), and pore-lining authigenic chlorite is well developed (Fig. 4.9). Both chlorite and minor smectite were identified on XRD from cuttings samples, however, smectite was not present within the core sample (Appendix A).

Interpretation

The *P. notensis* palynological zone is associated with a non-marine environment (Morgan 1994). Sedimentary structures and the overall large grain size suggest transport and deposition in a high-energy environment. In the South Australian Otway Basin, the Windermere Sandstone is interpreted to have been deposited in a low sinuosity fluvial environment that was in close proximity to a wedge of coarser grained sediments originating from the west (Morton et al. 1995).

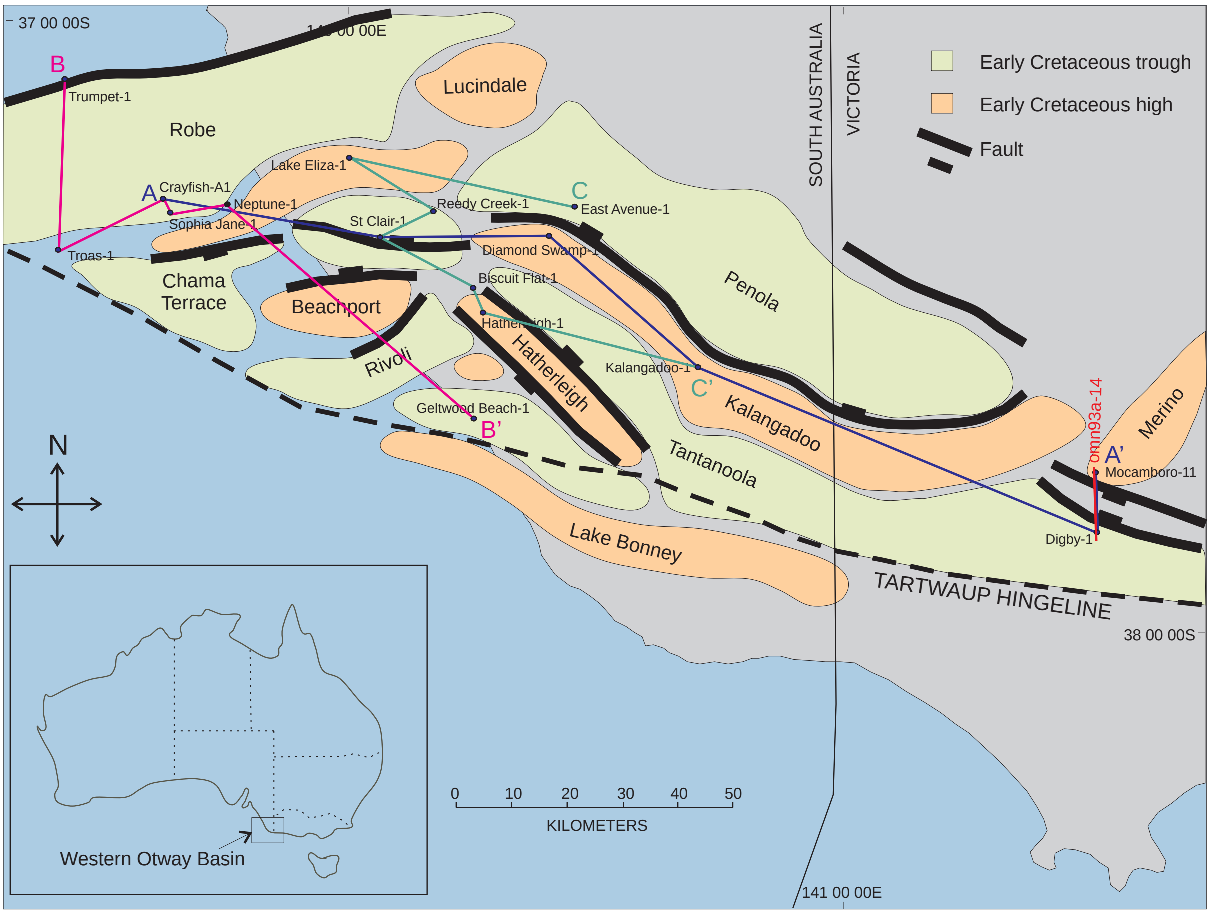

Figure 4.6 Structure map showing locations of sampled wells, cross-sections A-A', B-B' and C-C' and seismic line omn93a-14. Modified from Cockshell et al. (1995), Boult & Alexander (2002).

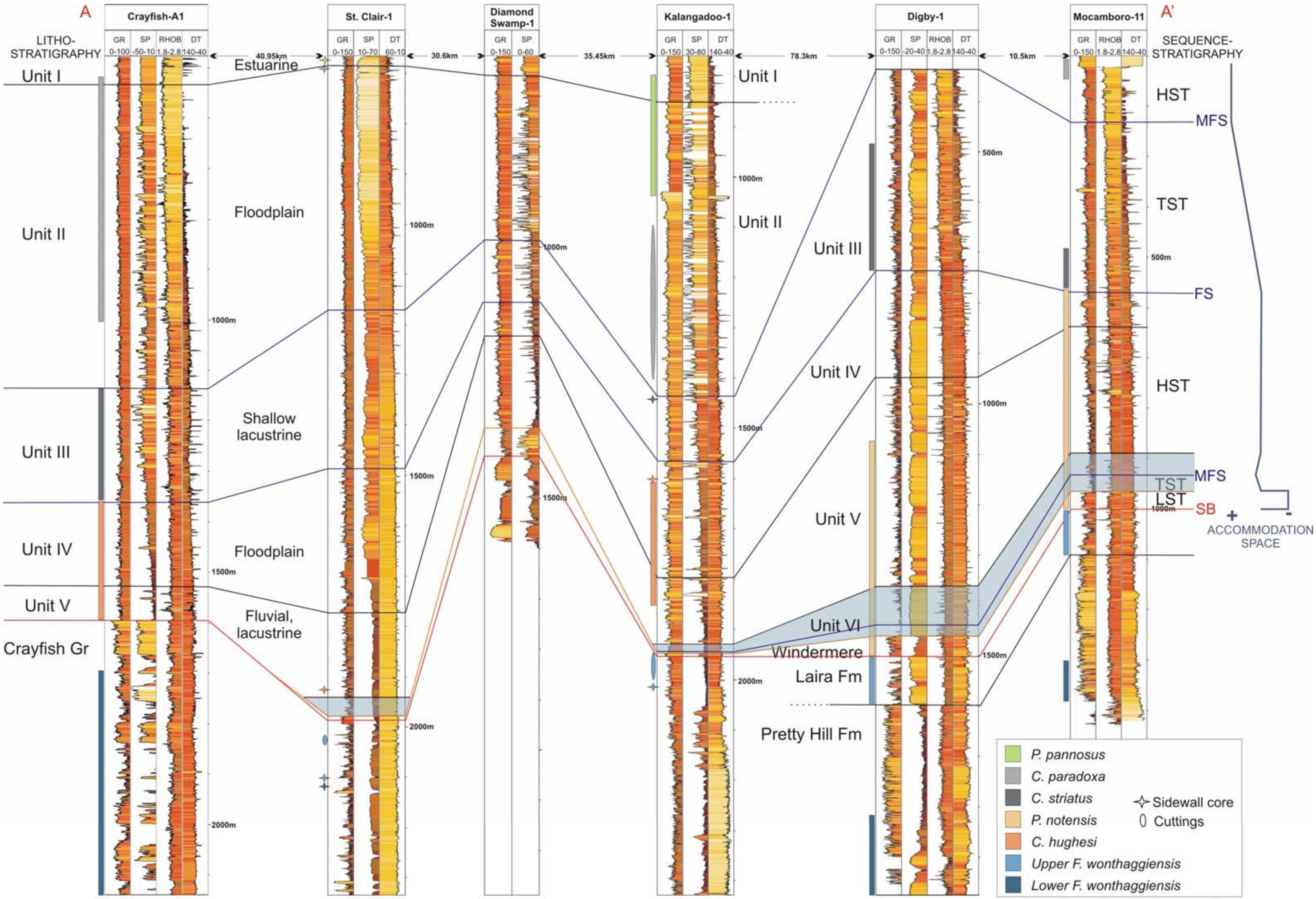

Figure 4.7a Log correlation panel A-A' showing the character and distribution of Eumeralla Formation Units VI to I. Unit VI is shaded in blue. Location of cross section is shown in Figure 4.6.

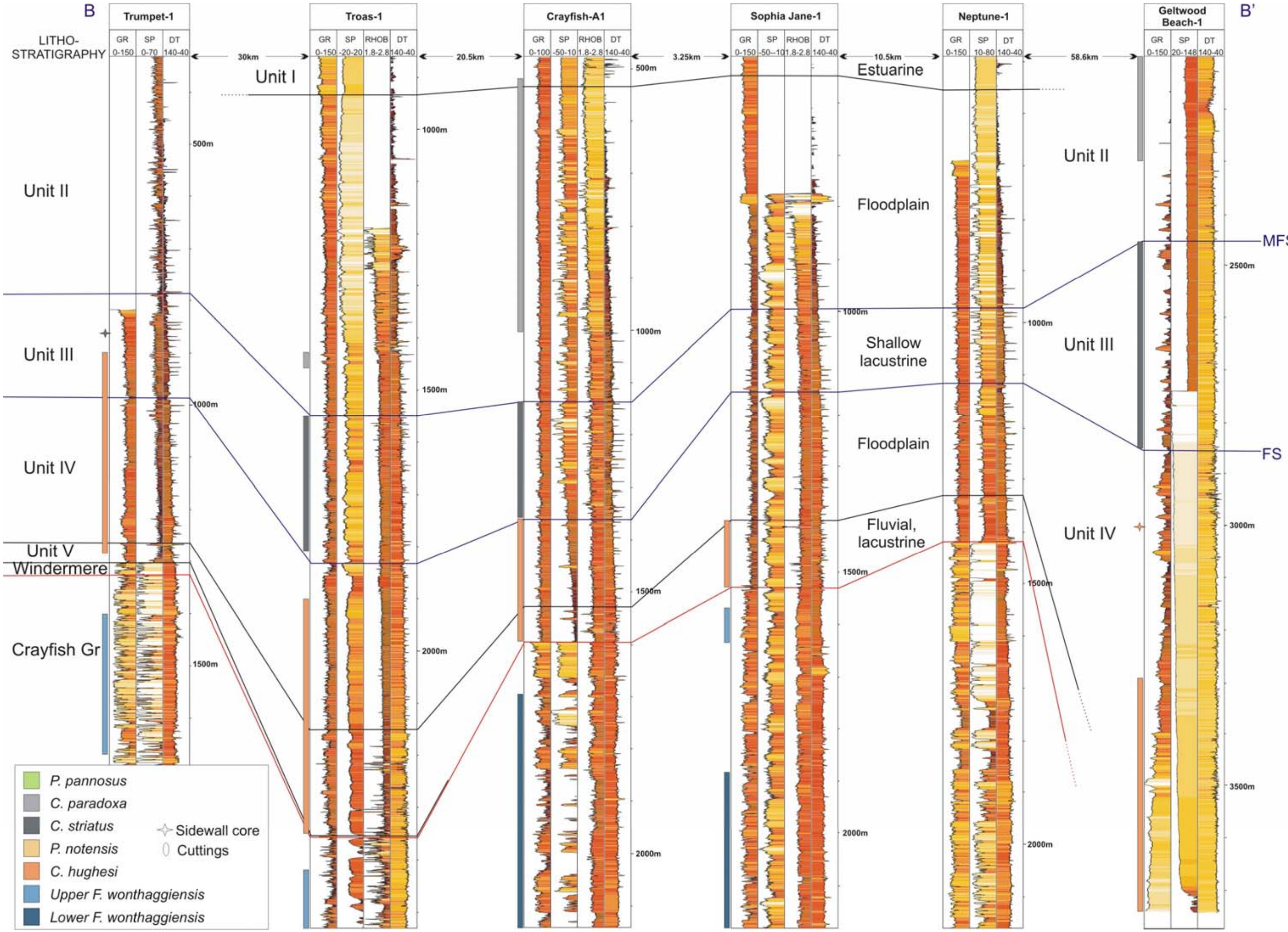

Figure 4.7b Log correlation panel B-B' showing the character and distribution of Eumeralla Formation Units VI to I. Location of cross section is shown in Figure 4.6.

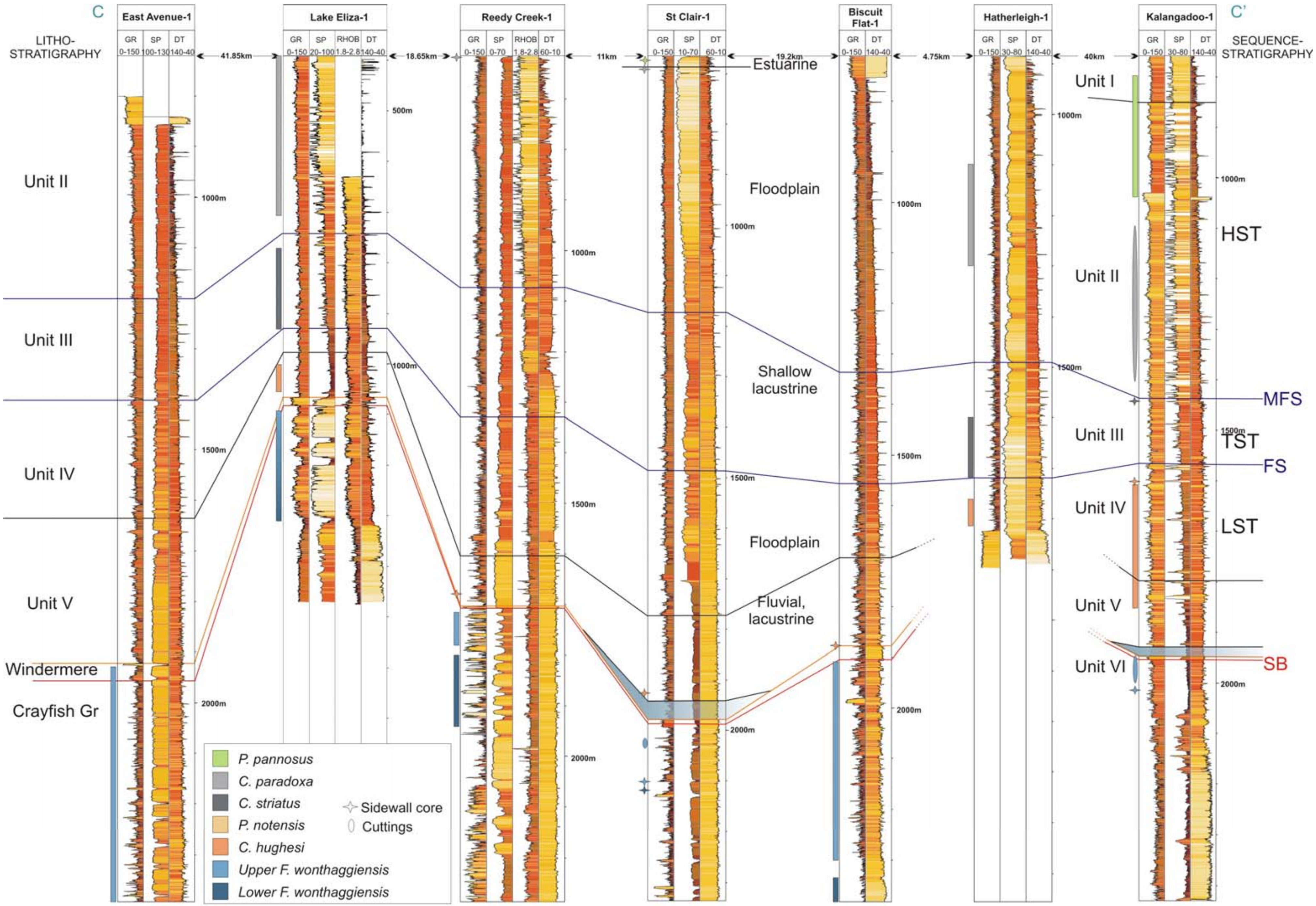

Figure 4.7c Log correlation panel C-C' showing the character and distribution of Eumeralla Formation Units VI to I. Unit VI is shaded in blue. Location of cross section is shown in Figure 4.6.

Windermere Sandstone Member
Mocamboro-11 Core 980.95m

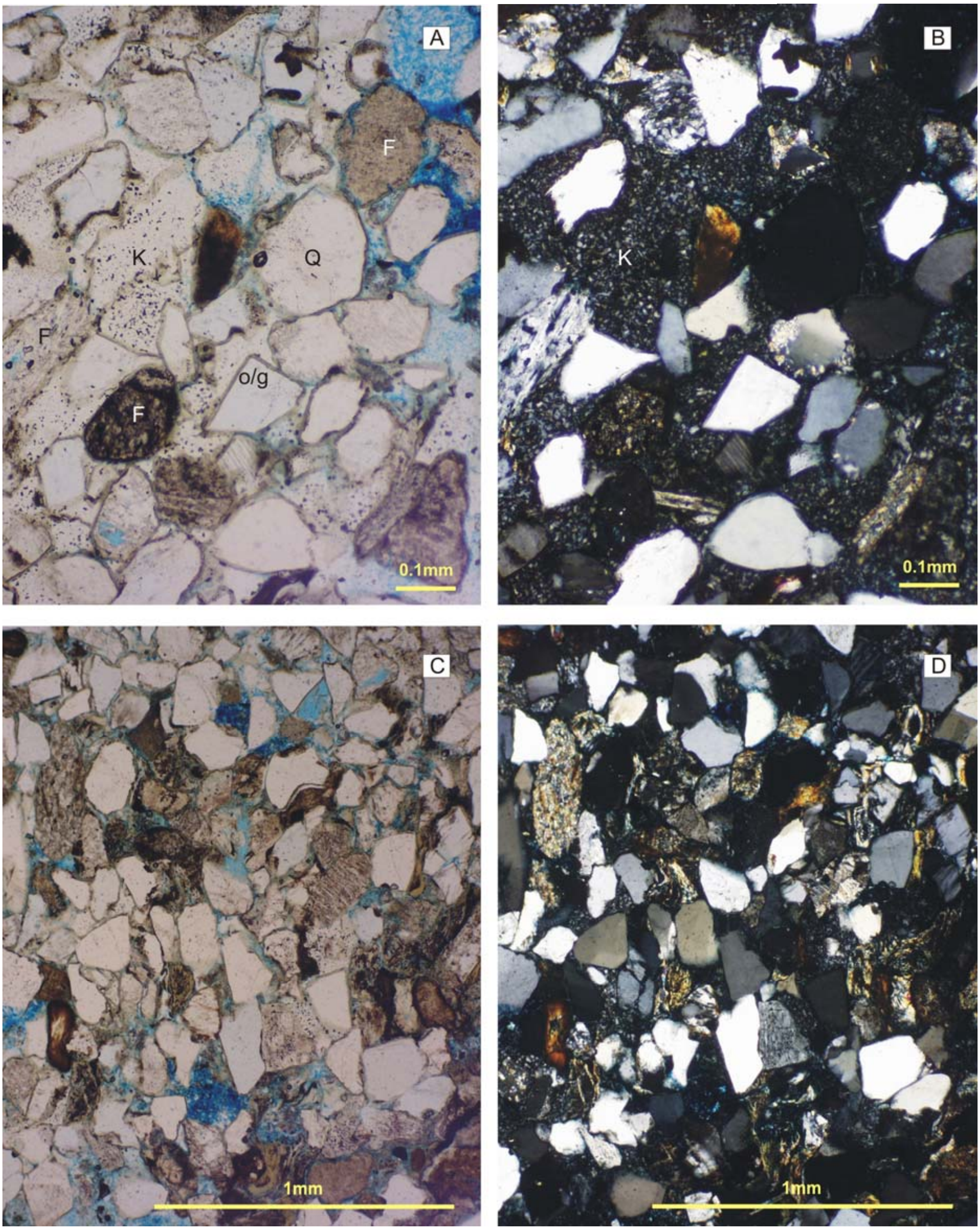

Figure 4.8
Thin sections from the Windermere Sandstone Member in plain light (A, C) and with crossed polars (B, D). The sediments are moderately sorted, and the grain size varies from fine to medium sand (~0.14-0.28mm). Grain contacts are mostly tangential. Minor sutured contacts occur. The framework grains are dominated by quartz and feldspar, and several quartz overgrowths occur (A). The feldspars are well rounded, while the quartz grains are sub rounded. Framework grains are rimmed by authigenic clays, and several embayments occur around the feldspar grains from dissolution. Kaolinite is well developed as pore-filling authigenic clay and reduces porosity. Secondary porosity has developed from dissolution of feldspar.

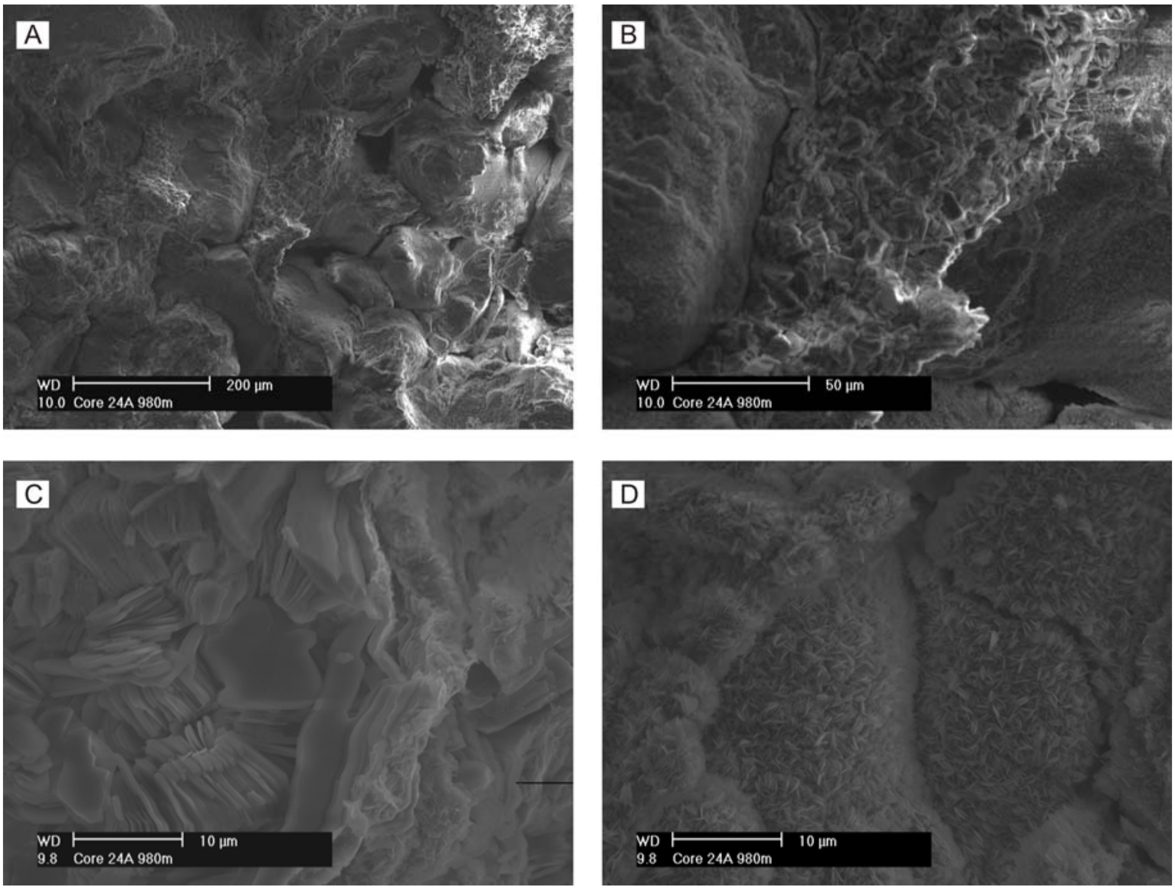

Figure 4.9 SEM images from the Windermere Sandstone Member in Mocamboro-11. Authigenic clays coat the coarse framework grains and reduce pore space (A). Kaolinite booklets occur as pore-filling authigenic clays (B, C), and pore-lining authigenic chlorite is well developed (D).

4.4 Eumeralla Formation Unit VI

Description

The basal Eumeralla Formation Unit VI is dominated by massive claystone and claystone with interlaminated and interbedded siltstone. Some sandstone interbeds occur in cuttings (Tabassi & Menhennitt 1991). The claystone is light to medium gray, micromicaceous, blocky and moderately firm. Organic material and well-sorted mud rip up clasts are common within the silty intervals. Unit VI is associated with a relatively uniform sonic log response (Fig. 4.7). SP and gamma ray log signatures are generally high and indicate a slight coarsening upward trend (Fig. 4.7). The interval occurs within the *P. notensis* palynological zone.

The sediments are clay and matrix-dominated (Figs 4.10). Very minor porosity occurs both within the fine-grained, clay-dominated sediments and within thin interbeds of coarser-grained, quartz-rich sediments (Fig. 4.10). Carbonaceous material is visible as elongated fragments that commonly are aligned parallel to the sample's laminations (Fig. 4.10). Illite is the dominant clay mineral, and the framework grain to matrix boundary is sharp (Fig. 4.11). Smectite is abundant, with particularly broad XRD-peaks occurring within the finest-grained sediments (Appendix A).

Illite-smectite and quartz are the dominant minerals within the massive claystone, with both constituting approximately 30-35% of the bulk mineralogy (Fig. 4.12). Albite is the dominant feldspar, and minor chlorite is present (Fig. 4.12). For the smallest grain size fraction (<2micron), the quartz content is significantly lower than it is within the bulk sample and illite-smectite makes up over 60% of the sediments (Fig. 4.12). Illite layers make up approximately 15% of the interbedded illite-smectite layers (Fig. 4.12).

Interpretation

The basal Eumeralla Formation is associated with a non-marine environment indicated by a diverse range of pollen and spores and a total absence of saline markers (Morgan 1994). The fine-grained sediments and their lack of sedimentary structures suggest this interval represents lacustrine conditions. Mud rip-up clasts, siltstones and minor sandstone interbeds probably resulted from small-scale density currents.

4.5 Unit V

Description

Unit V consists of interbedded siltstones, mudstones, sandstones and coals. The siltstones commonly occur at the bottom of fining-upward sequences (Fig. 4.13, Appendix B and C), and have an erosive base and trough cross bedding is common. Pebble-sized, rounded to sub-angular siltstone clasts are present both within these sequences and as thin horizons within the mudstone. Planar cross bedding occurs in thin siltstone interbeds. Mud rip up clasts and soft-sediment deformation occur within some sections (Appendix B). Organic content varies from rare to abundant, and some root traces occur towards the top of the unit. Slickensides are developed in core from fault movement (Appendix B). Overall, the SP log typically shows that the sediments are coarsening upward (Fig. 4.7). In some wells, a relatively fine-grained interval dominated by siltstones and mudstones is developed in the lower part of Unit V. This lower section can easily be distinguished from the upper Unit V, which contains sandstones and coal beds that are clearly visible on logs. Unit V generally occurs within the *P. notensis* palynological zone.

Eumeralla Fm Unit VI
Mocamboro-11 Core 907.2m

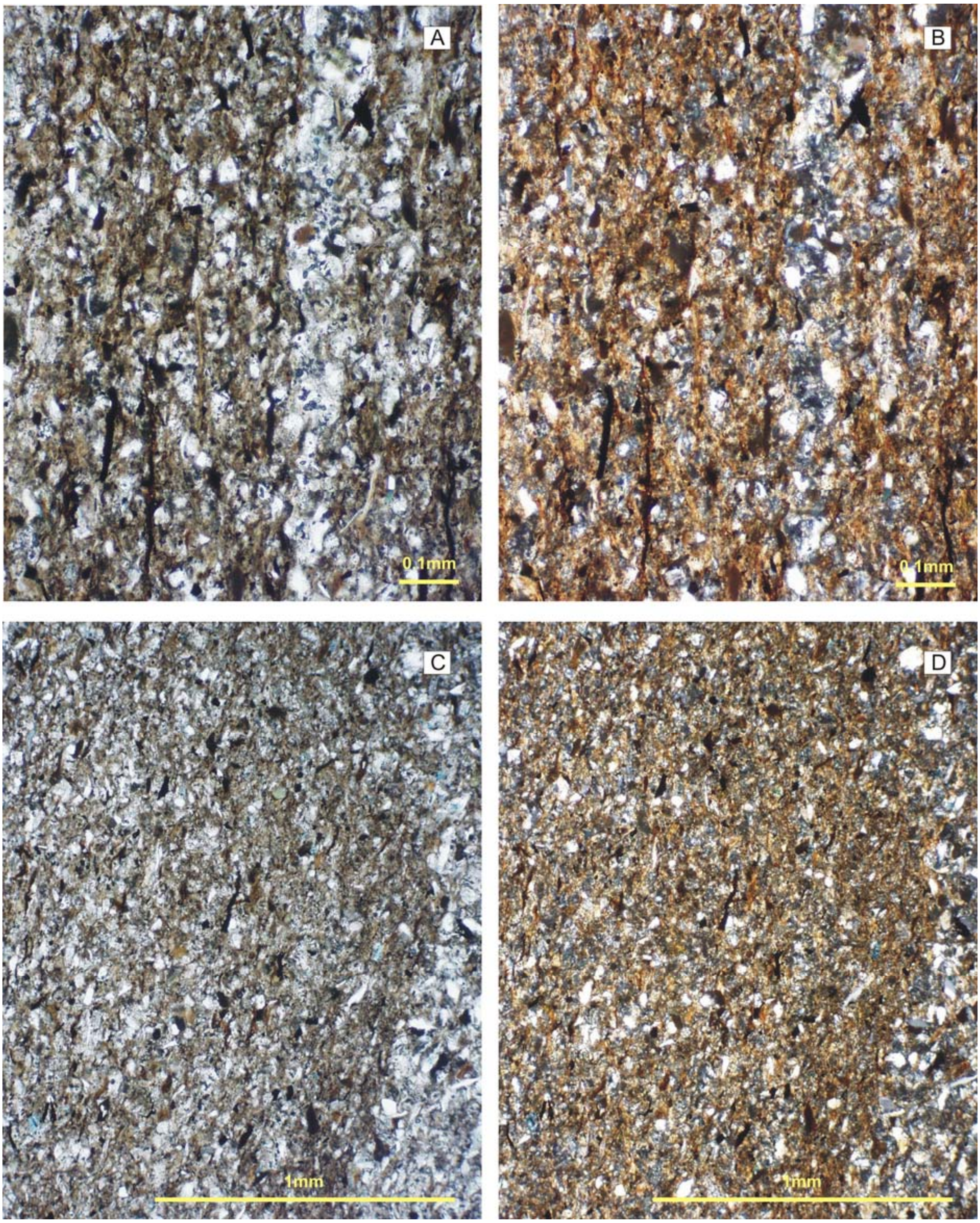

Figure 4.10
Thin sections from a relatively coarse interval within Eumeralla Formation Unit VI in plain light (A, C) and with crossed polars (B, D). The sediments are fine-grained and matrix-dominated. Some framework grains are present, particularly within the thin, coarser-grained laminations. The largest quartz grains are within the coarse silt range, but the majority of the visible framework grains (both quartz and feldspar) occur in a fine to medium silt size. Carbonaceous material is visible as elongated, dark brown flecks, which commonly are aligned parallel to the laminations within the sample. There is minor visible porosity both within the quartz-dominated and within the fine-grained, matrix-dominated intervals. The porosity only occurs as isolated pores.

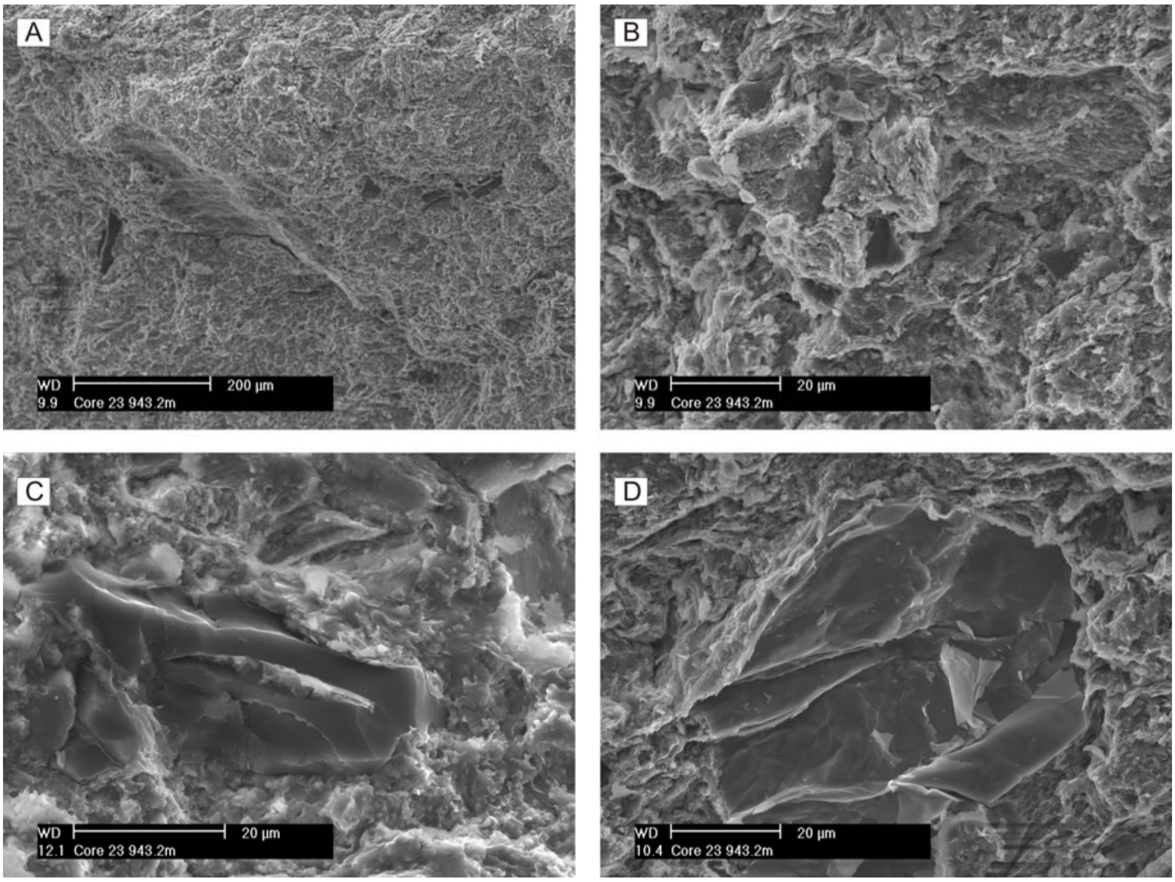

Figure 4.11 SEM images from Unit VI in Mocamboro-11. The sediments are clay and matrix-dominated, with only isolated quartz grains visible (A, B). The framework grain to matrix boundary is sharp, suggesting there has not been any significant dissolution of the quartz (C, D). Illite is the dominant authigenic clay mineral (C, D).

Sediments within the lower Unit V are moderately to well sorted and the framework grains are dominated by quartz, feldspar and mica (Fig. 4.14). Porosity is best developed within quartz-rich layers, which contain less mica and clays (Fig. 4.14). Some secondary porosity has developed from dissolution of feldspar (Fig. 4.14). Illite is the dominant clay mineral and is very tightly packed around the framework grains (Figs 4.14, 4.15). Detrital mica and authigenic chlorite platelets are partly replaced and surrounded by illite (Fig. 4.16). The non-wispy appearance of the illite suggests it is most likely a replacement mineral and not a detrital one (Fig. 4.16) (R. Pollock pers. comm.)

Within the coal-rich intervals of Unit V, the sediments are very fine-grained, heterogeneous and matrix-dominated (Fig. 4.17). There are no laminations and no visible porosity (Fig. 4.17). Large coal fragments and isolated, well-rounded quartz grains are surrounded by illite (Figs 4.17, 4.18). Smectite is visible as small marks on the surface of the quartz grains (Fig.

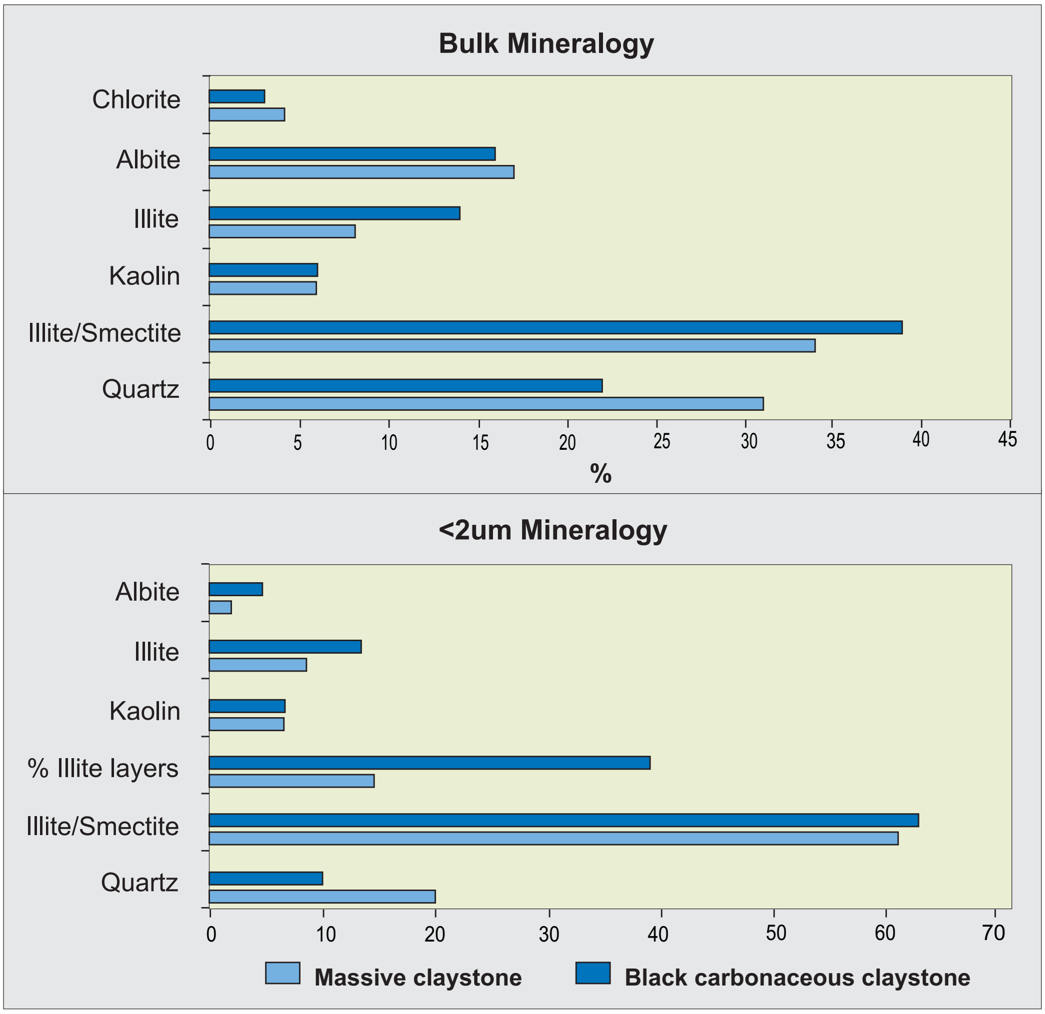

Figure 4.12 Bulk mineralogy and <2μm mineralogy of two fine-grained Eumeralla intervals in Mocamboro-11 from quantitative clay analysis. The massive claystone represents Unit VI, and the black carbonaceous claystone occurs within the coal-rich Unit V.

4.18). Illite-smectite constitutes almost 40% of Unit V's bulk mineralogy, whereas quartz makes up 23% and albite and illite about 15% (Fig. 4.12). Both kaolin and chlorite are present in minor amounts (Fig. 4.12). For the clay size fraction (<2 micron), illite-smectite constitutes over 60% of the sediments and the quartz and albite content only amounts to 10% and 5% respectively (Fig. 4.12).

Overall, the sediments within Unit V are very varied. Fine-grained, matrix-dominated intervals are interbedded and interlaminated with coarser-grained, quartz-rich sediments (Fig. 4.19). Calcite is common within cuttings from a very carbonaceous-rich siltstone. Smectite is present in sediments throughout the unit (Appendix A).

Figure 4.13 Core photo from the Eumeralla Formation in Crayfish-1A showing multiple fining-upward sequences (yellow) within Unit V. The bottom of the Eumeralla Formation core is marked with a white arrow at 1529.8m. Base of the Eumeralla Formation in this well is at 1596.8m.

Eumeralla Fm in lower Unit V
Mocamboro-11 Core 871.4m

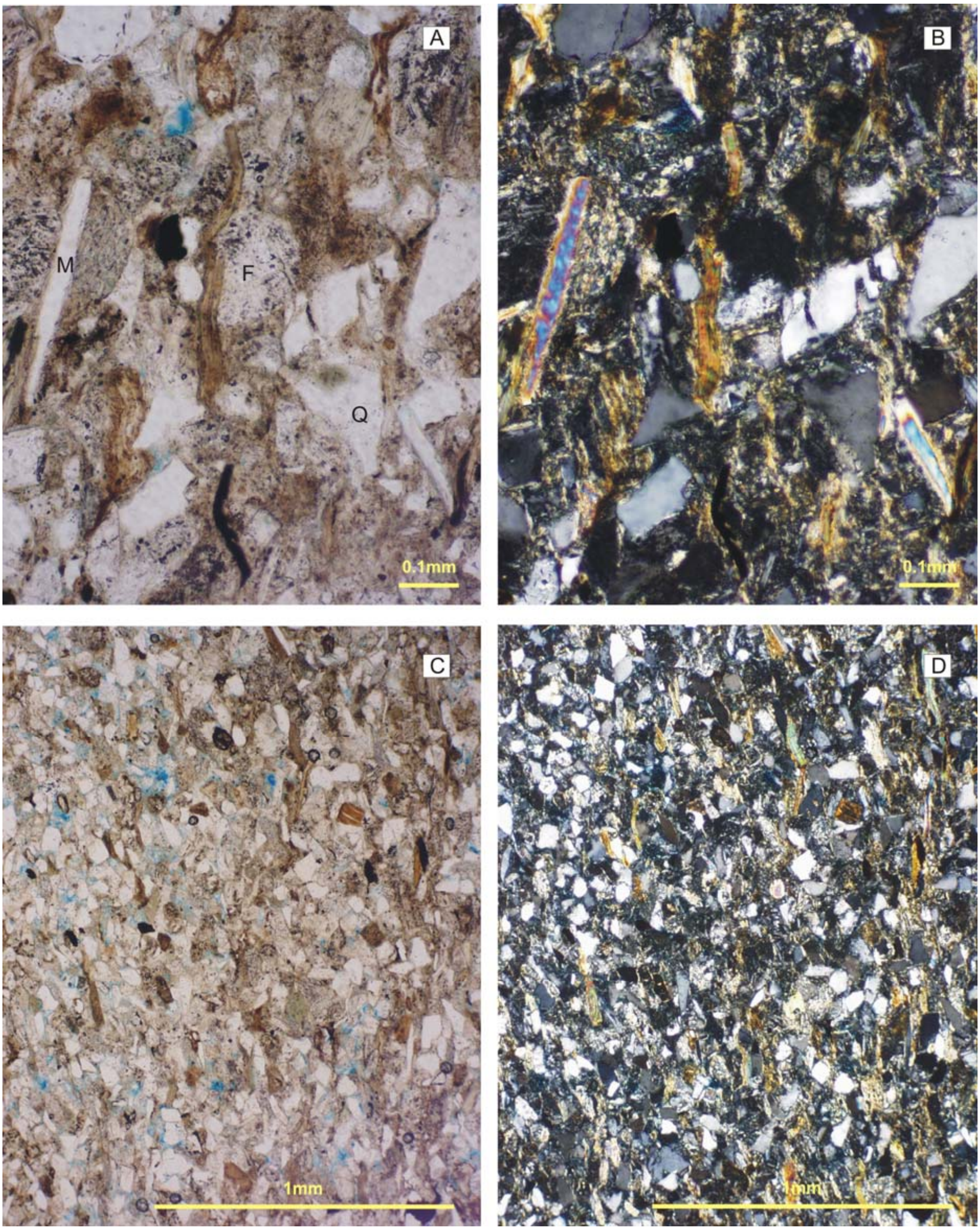

Figure 4.14
Thin sections from the lower Unit V in plain light (A, C) and with crossed polars (B, D). The sediments are moderately to well sorted. The dominant grain size is fine to very fine sand. Grain contacts are tangential to sutured. The framework grains are dominated by quartz, feldspar and mica. Mica occurs as elongated bow ties, and quartz overgrowths are common. Chlorite is seen as a brownish-green clay (C). Minor carbonaceous material is present as elongated flecks. Framework grains are surrounded by authigenic clay. Porosity is best developed within quartz-rich laminations (left part of A, D), which contain less mica and clays. Secondary porosity has developed from dissolution of feldspar.

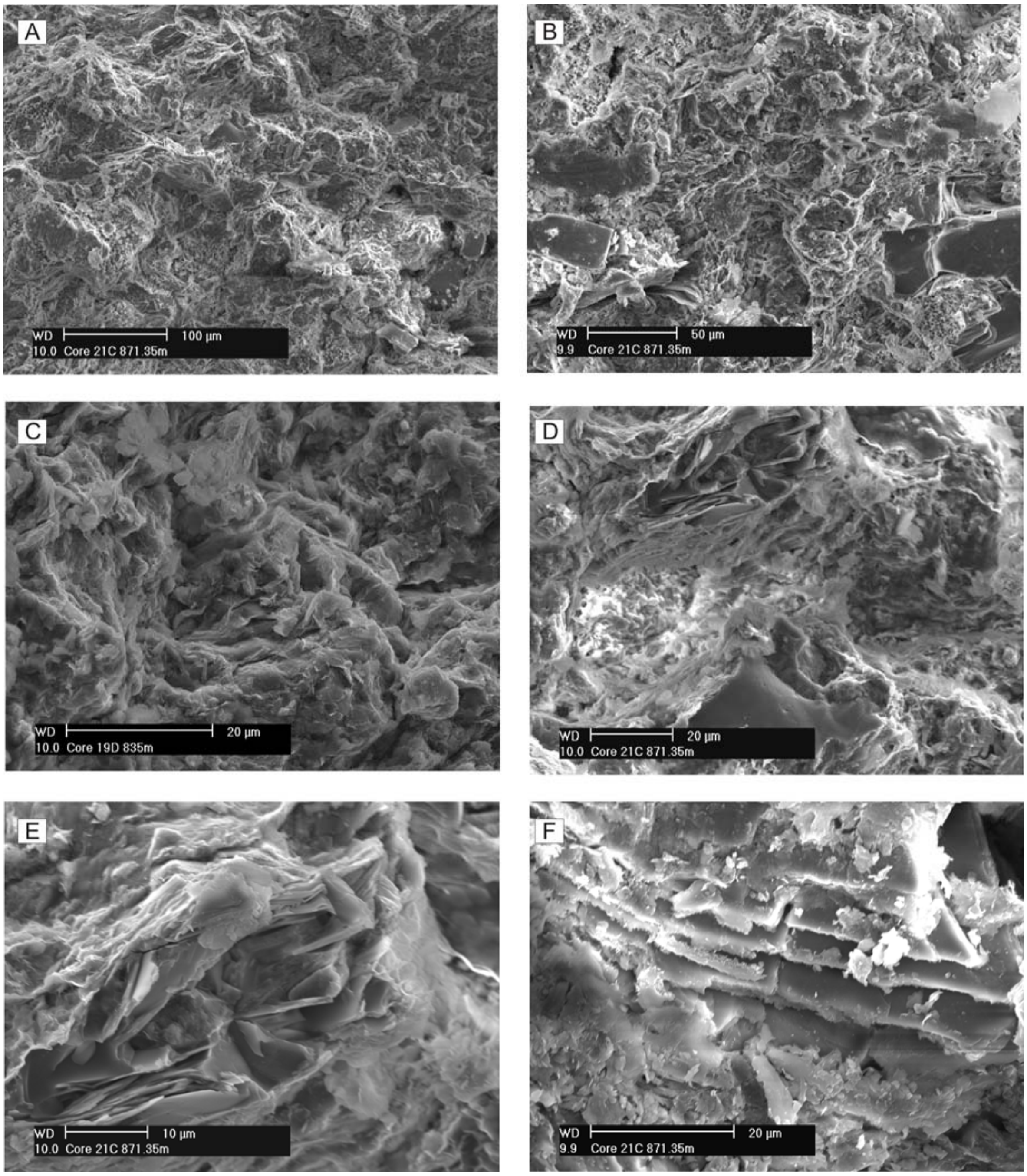

Figure 4.15 SEM images from the lower Unit V in Mocamboro-11. Quartz grains are surrounded by clay matrix (A, B). Illite is the dominant clay mineral (C), and is very tightly packed around the quartz grains (D, E). Clay mineralisation occurs along the edges of what might represent calcareous or carbonaceous material (F).