

The Mallina Formation, Constantine Sandstone and Whim Creek Group: a new stratigraphic and tectonic interpretation for part of the western Pilbara Craton

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Abstract

Detailed regional mapping of MOUNT WOHLER and SHERLOCK, and recent SHRIMP U-Pb zircon dates, permit a re-interpretation of the depositional and tectonic environment under which the sedimentary and volcanic rock successions of the Mallina Synclinorium and the Whim Creek Group accumulated in the western part of the Pilbara granite-greenstone terrain. Variations in the basal successions of the Constantine Sandstone, forming the lowest and oldest unit of the northeast-trending Mallina Synclinorium, reflect a rapidly subsiding depositional basin, with a hinterland to the southeast. Distal facies of the c. 3000 Ma Mallina Formation, which forms the upper unit of the synclinorium, onlap the c. 3010 Ma volcano-sedimentary rocks of the Whim Creek Group, which form the northwestern margin of the synclinorium. The Mallina Synclinorium is interpreted to represent a backarc basin that developed behind the magmatic arc represented by the Whim Creek Group.

KEYWORDS: Pilbara, granite-greenstone terrain, Constantine Sandstone, Mallina Synclinorium, Whim Creek Group

The geology of the MOUNT WOHLER – SHERLOCK* area (Fig. 1), in the western part of the Pilbara granite-greenstone terrain, is dominated by three rock units: the Constantine Sandstone, the Mallina Formation, and the Whim Creek Group. The first two are the result of deep-water deposition from turbidity currents (i.e. turbidites). The Whim Creek Group is a calc-alkaline volcano-sedimentary sequence deposited in subaerial and later, subaqueous environments. Kriewaldt and Ryan

(1963) and Ryan and Kriewaldt (1964) interpreted the evolution of these sequences in terms of a subsiding trough (the Mallina Synclinorium) with a clastic sedimentary fill (Constantine Sandstone and overlying Mallina Formation) and contemporaneous volcanism along a stable northwest margin. This interpretation was embraced by Fitton et al. (1975) and Horwitz (1979, 1990), who placed all of the sequences into their 'Whim Creek Group'. Hickman (1990), however, suggested that the Constantine Sandstone – Mallina Formation succession was distinct

from, and older than, the volcano-sedimentary sequence and included this succession in the De Grey Group.

Horwitz (1979, 1990) described an unconformity at the base of the Constantine Sandstone and recent mapping of the MOUNT WOHLER sheet has uncovered further exposures of that unconformity. All of these studies identify regional lithological variations in the basal portion of the Constantine Sandstone and constrain evolutionary models for the Mallina Synclinorium. Additional constraints are gained from detailed mapping of the area and from geochronological data. This paper describes the nature and outcrop distribution of the Constantine Sandstone, and incorporates this into a preliminary tectonic model for the eastern part of the western Pilbara Craton.

Local geology

The Mallina Synclinorium is composed of the Constantine Sandstone and the conformably overlying Mallina Formation. These rocks have been intruded by granitoids and subjected to at least four phases of deformation (Smithies, in prep.). The northwest flank of the synclinorium is in faulted contact with the Whim Creek Belt, which hosts the Whim Creek Group. On the southeast flank, the Constantine Sandstone

* Capitalized names refer to standard map sheets

rests unconformably on a sequence of ferruginous chert and mafic to ultramafic volcanics, tentatively correlated with the Gorge Creek Group of the eastern Pilbara Craton. A layered mafic-ultramafic intrusion – the Millindinna Complex of Fitton et al. (1975) – was emplaced along much of the length of the unconformity.

The Constantine Sandstone and basal unconformity

Outcrops of the Constantine Sandstone are restricted to the southern parts of the synclinorium, with conglomerate-rich facies confined to the southeast margin. Throughout most of its exposure on MOUNT WOHLER, the formation is dominated by medium- to coarse-grained feldspathic sandstone, grit and shale, which are either interbedded on a scale of 1 to 20 m, or individually form relatively homogeneous units from 300 to 1000 m thick. The coarser grained units contain rare and discontinuous pebble beds. No trough cross-bedding is observed, but poorly developed graded bedding is common. Eriksson (1982) interpreted these rocks as turbidites, representing various depositional environments on a submarine fan.

The basal unconformity to the Constantine Sandstone is exposed at four localities on MOUNT WOHLER. In the core of the Croydon Anticline and in the eastern part of the Powereena Anticline the basal unit of the formation is medium- to coarse-grained feldspathic sandstone. However, in the western part of the Powereena Anticline and to the south at Nunyerry Gap the basal unit of the Constantine Sandstone ranges from medium-grained lithic sandstone to conglomerate. It unconformably overlies silicified shale and ferruginous chert of a succession which Hickman (1990) interpreted by to be part of the Gorge Creek Group. The conglomerate-lithic sandstone succession is only thinly developed in the western part of the Powereena Anticline, but is up to 1300 m thick at Nunyerry Gap.

The local geology of the Nunyerry Gap area is shown in Figure 2. Conglomerate containing randomly orientated (chaotic) angular blocks of chert, up to 2 m in size, supported in

a matrix of medium- to coarse-grained, poorly sorted lithic sandstone, marks the unconformity with the chert. The succession above the unconformity fines upwards from conglomerate to interbedded medium-grained sandstone and shale, and is interpreted to represent a proximal submarine-fan succession.

The upward-fining submarine-fan succession at Nunyerry Gap is conformably overlain by the feldspathic sandstone, grit and shale succession that typifies the Constantine Sandstone elsewhere on MOUNT WOHLER, and which Eriksson (1982) interprets as lobe and basin-plain deposits. The overall succession of the Constantine Sandstone thus represents an upward transition from deposition in a proximal submarine fan to a distal deeper water environment, namely a subsiding sedimentary basin. Furthermore, the thinning of the basal conglomerate-sandstone succession from Nunyerry Gap to the western part of the Powereena Anticline, and the absence of that succession from all exposures of the unconformity farther to the north, establishes a northerly trend from proximal to distal depositional environments. These lateral facies changes occur over a short distance and indicate a steep palaeoslope, away from a hinterland to the south or southeast. Fitton et al. (1975) describe conglomerate at the base of the Constantine Sandstone near the Teichmans gold mine, about 40 km to the northeast of Nunyerry Gap. It is possible that similar submarine-fan deposits characterize, and are restricted to, the southeastern margin of the Mallina Synclinorium.

Constraints on a model for the MOUNT WOHLER-SHERLOCK area

Geochronology and detailed mapping of MOUNT WOHLER and SHERLOCK have identified the following constraints on the geological evolution of the area.

- Smithies (in prep.) presents evidence that the Mallina Formation shows a general decrease in average grain size from the southern parts of MOUNT WOHLER towards the Whim Creek Belt, indicating a northwest trend to more distal depositional facies.

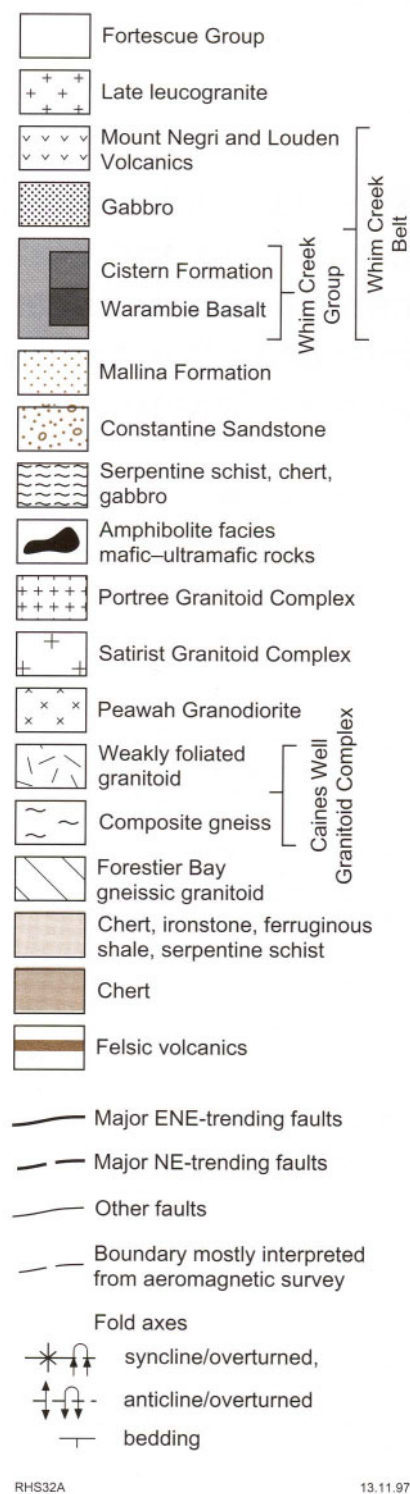
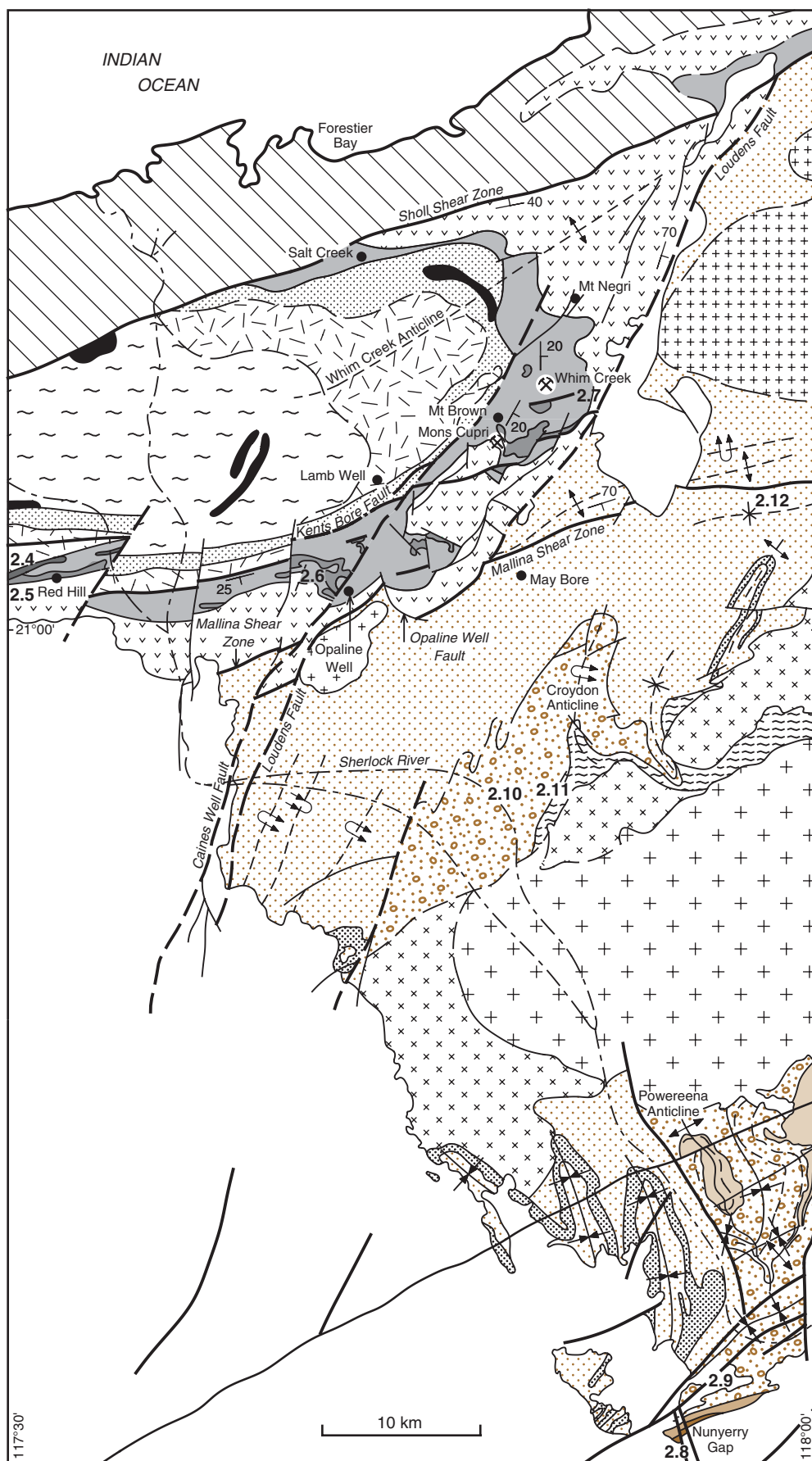


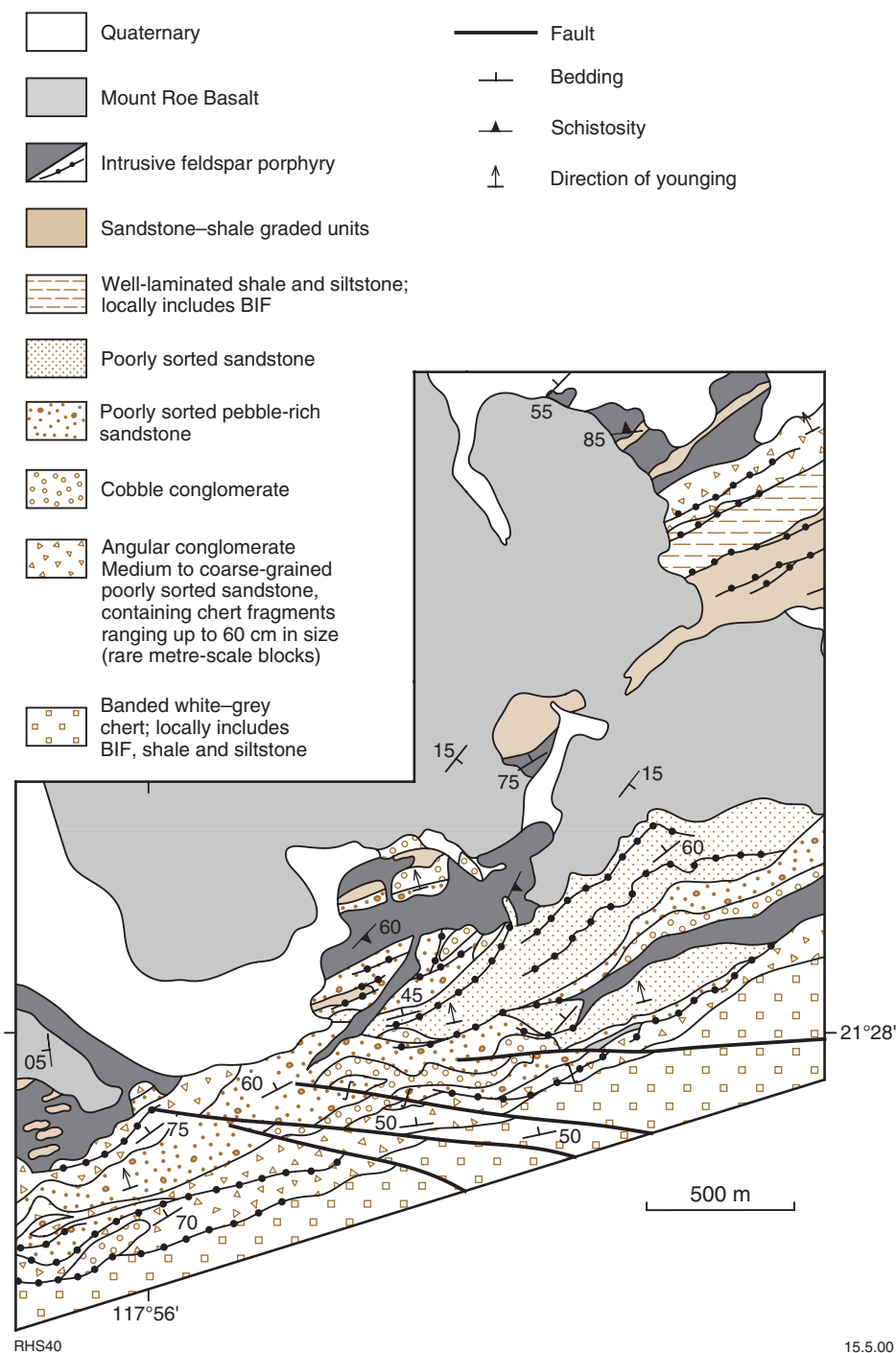
Figure 1. Geology of the central Western Pilbara granite-greenstone terrain

- Nelson (1997) has dated detrital zircons from the Mallina Formation to indicate a maximum age of deposition of 2997 ± 20 Ma. Few, if any,



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zircons could have been derived from sources to the northwest of the Mallina Synclinorium; in particular, from the c. 3010 m.y. Whim Creek Group. Most of the detrital zircons were between 200 and 500 m.y. older than the maximum age of the Mallina

Formation, with ages similar to many rocks found to the southeast.

- Smithies et al. (in prep.) interpret the Whim Creek Belt not as a small ensialic pull-apart basin that marks the original

depositional extent of the Whim Creek Group (cf. Barley, 1987), but rather as the down-faulted remnants of an originally more extensive calc-alkaline volcanosedimentary succession. In this interpretation, the Whim Creek Group formed in an extensional

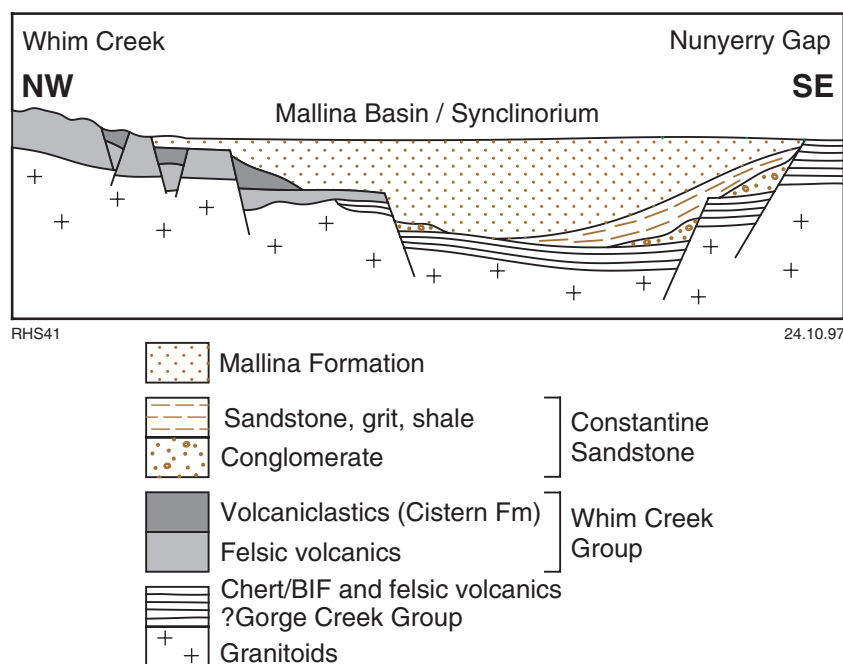


Figure 3. Schematic cross section of the Mallina Synclinorium

tectonic setting; deposition was predominantly subaerial, but in the later stages was clearly subaqueous.

- Smithies et al. (in prep.) dated dacitic tuff of the Cistern Formation, in the middle to upper part of the Whim Creek Group (of Hickman, 1990), at 3009 ± 4 Ma indicating that the group is older than the Mallina Formation, and possibly also older than the Constantine Sandstone.
- Krapez and Barley (1987) suggest that the faulted contact between the rocks of the Mallina Synclinorium and the Whim Creek Group represents a tectonostratigraphic domain boundary. However, Fitton et al. (1975), Horwitz (1979, 1990) and Smithies et al. (in prep.) find no evidence for significant strike-slip movement along that fault. Rather it represents a major basin margin.

Preliminary thoughts on a model

Figure 3 is a schematic cross section providing an interpretation of the depositional environment of the Constantine Sandstone and Mallina Formation. The section depicts a basement composed of chert (?Gorge Creek Group) and gneiss overlain to the north by the calc-alkaline volcanic rocks (lower half of the Whim Creek Group), and faulted to the southeast to produce the scarp that marked the edge of the Mallina Basin (Synclinorium). Development of the basin was asymmetric, with the northwestern edge subsiding less than the southeastern edge. During faulting along the northwestern edge, the Cistern Formation accumulated from a combination of detritus derived from erosion of the calc-alkaline volcanics and renewed andesitic to dacitic volcanism. An extensive series of submarine fans was developed along the

southeastern edge of the basin at this time. The fans extended northwards to deposit progressively more distal sedimentary facies within the Constantine Sandstone. The southeastern hinterland included continental material some 200 to 500 m.y. older than the sandstone. As the basin subsided further, the Whim Creek Belt was submerged and the Mallina Formation was deposited. Fine-grained turbiditic sedimentary rocks (Rushall Slate – Hickman, 1990) overlying the Cistern Formation of the Whim Creek Group probably represent a distal onlapping facies of the Mallina Formation.

The geological evolution, as described here, is consistent with formation of a continental magmatic arc (Whim Creek Group) and partial destruction and burial of that arc during the development of a backarc basin (Mallina Basin/Synclinorium).

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