Libyan Journal of Science & Technology 7:1 (2018) 24–31

Faculty of Science - University of Benghazi
Libyan Journal of Science & Technology
(Formerly known as Journal of Science & It's Applications)
journal home page: www.sc.uob.edu.ly/pages/page/77

Petrography of heavitree quartzite, Amadeus basin, central Australia: Implications on depositional environment, provenance and tectonic setting

Farag M. EL Oshebi [a,b,*], Osama R. Shaltami [a,b], Fares F. Fares [a,b], Hwedi Errishi [b,c], and Salah S. El Ekhfifi [d]

[a]*Department of Earth Sciences, Faculty of Science, Benghazi University, Libya*
[b]*Department of Oil and Gas Engineering, Faculty of Engineering, Libyan Canadian University of Modern Sciences, Libya*
[c]*Department of Geography, Faculty of Arts, Benghazi University, Libya*
[d]*Department of Exploration, National Oil Corporation, Benghazi, Libya*

ARTICLE INFO

Article history:
Received 30 December 2017
Revised 14 January 2018
Accepted 08 February 2018
Available online 21 February 2018

Keywords:
Neoproterozoic; Diagenesis; Paleoclimate; Amadeus Basin; Australia.

* Corresponding author:
E-mail address: farag.issa@uob.edu.ly
F. M. El Oshebi

ABSTRACT

Petrographic analysis of the Neoproterozoic Heavitree Quartzite from the Amadeus basin, central Australia was used to interpret the depositional environment, paleoclimate, provenance and tectonic setting. The studied sandstones are mainly classified as quartz arenites. The depositional environment of the Heavitree Quartzite is deltaic based on composition and maturity. The probable paleoclimate for the source area of the Heavitree Quartzite is humid. The detected quartz grains suggest that granitic rocks must be the plausible source of the studied sediments. The studied samples plot in the field of craton interior in the tectonic discrimination diagrams.

1. Introduction

The Amadeus basin is one of the major intracratonic sedimentary basins situated in central Australia. It is an integral component of the Centralian Superbasin that also involves the Officer, Ngalia and Georgina basins (Fig. 1). These intracratonic sedimentary basins have approximately similar rock units that demonstrate the upper part of Precambrian (Neoproterozoic) to Paleozoic (Walter *et al*., 1995; Hill and Walter, 2000; El Oshebi, 2017). The Amadeus basin is about 170,000 km^2, extending to west into Western Australia and the south in the direction of the Northern Territory (Fig. 2). There is confirmation for in excess of 14 km thick deposits of non-marine and marine sedimentary successions from Neoproterozoic to Late Paleozoic, an era of ~550 Ma (Wade et al., 2005). Fig. 3 represents the distribution of sediments in the Amadeus basin. The majority accessible data of Neoproterozoic provenance propose that the source of deposits in the basin was local and sediments were derived from Arunta Region Musgrave Province and Gawler Craton after uplifting and erosion (Maidment *et al*., 2007). In this study, the Heavitree Quartzite is divided into seven units, these units composed mainly of sandstones with intercalations of a few mudstone beds (Fig. 4). The present work is done to achieve the following:

1) Study the petrography of the Heavitree Quartzite, Amadeus basin, central Australia.

2) Determine the depositional environment, paleoclimate, provenance and tectonic setting of the studied formation.

A review of the literature has revealed that there are limited sedimentological studies in the Amadeus basin. Previous studies have interpreted the depositional environments of the Precambrian rocks based on rock composition (e.g., Prichard and Quinlan, 1962). The depositional environment of the Heavitree Quartzite was interpreted to be fluvial to shallow marine (Lindsay, 1999). Provenance studies have determined sediment provenance of the Neoproterozoic to Devonian sections of the Amadeus basin based on detrital zircon and isotope analysis (e.g., Zhao *et al*., 1991; Maidment *et al*., 2007). The Heavitree Quartzite, Aregonga Formation, Pioneer Sandstone, Pertatataka Formation, Arumbera Sandstone, Todd River Dolomite, Carmichael Sandstone and Pertnjara Group have a widespread distribution in the northwest and northeast of the Amadeus basin (Wells *et al*., 1966).

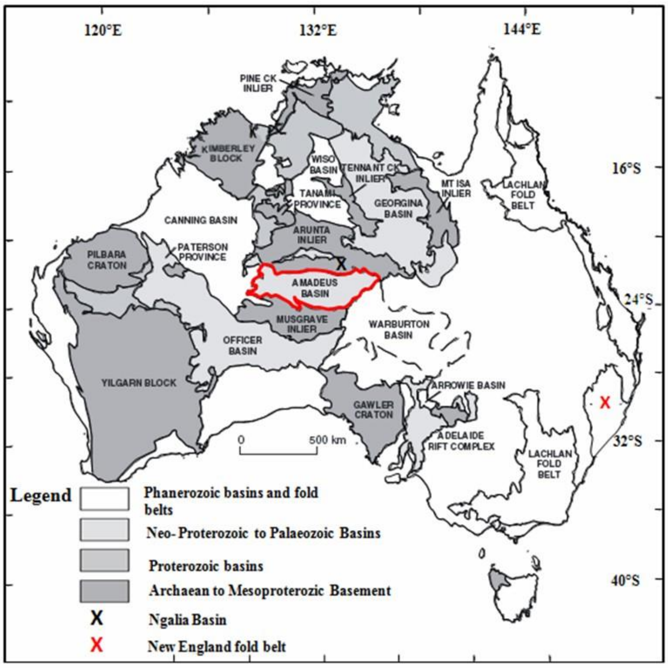


Fig. 1. The Australian intracratonic sedimentary basins that comprise the Amadeus basin (red outline), Georgina basin, Officer basin and Ngalia basin (modified after Maidment *et al*., 2007).

However, these depositional units are not well described and the available data are not enough to represent these thick formations, which have different depositional environments and processes. There is a contradiction in interpretation of depositional environment interpretations due to a lack of sedimentological investigations. There is a lack of paleocurrent data in the Amadeus basin and most available data suggest theories of paleocurrent directions without supported convincing evidence (Maidment *et al.*, 2007). The paleocurrent observations in the Amadeus basin depended on tectonic evolution and zircon and isotopic analysis. Detailed sedimentological observations such as lithofacies analysis and sedimentological logs have not been made for the paleocurrent and depositional environment interpretations. Further detailed sedimentological studies would be useful looking at lithology (grain size and sedimentary structures) in conjunction with vertical trends. These would be helpful for depositional environment interpretations, paleocurrent investigations and any future studies.

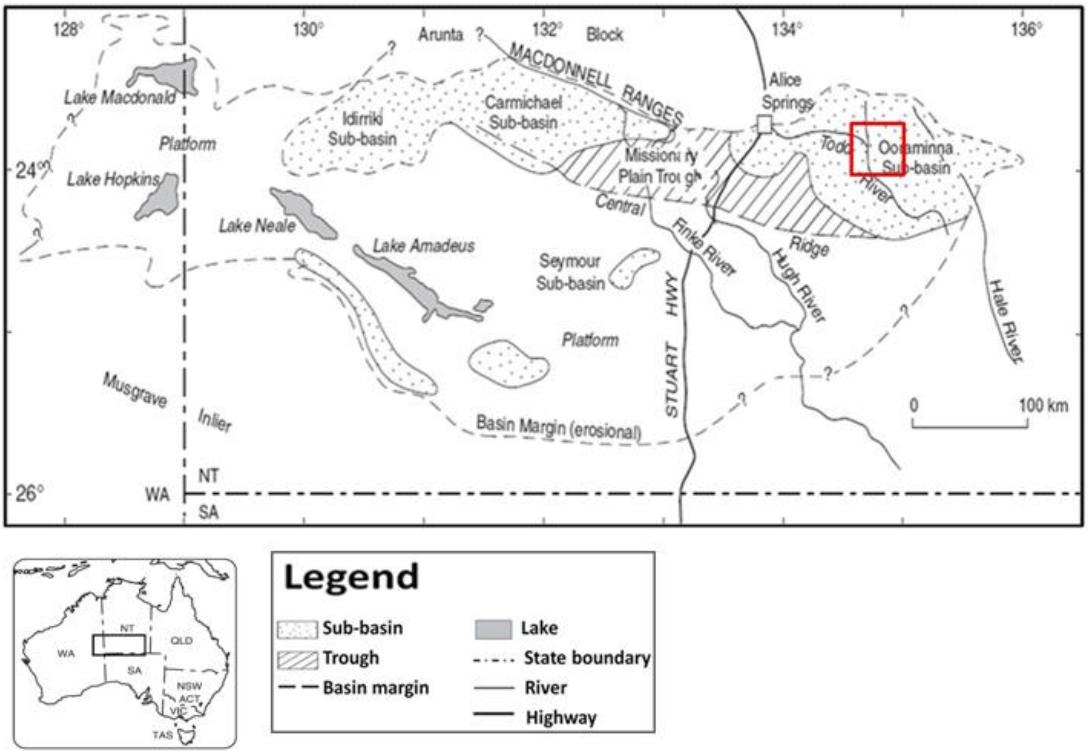


Fig. 2. Major morphological features of the Amadeus basin, the study area in red square (modified after Lindsay and Korsch, 1991).

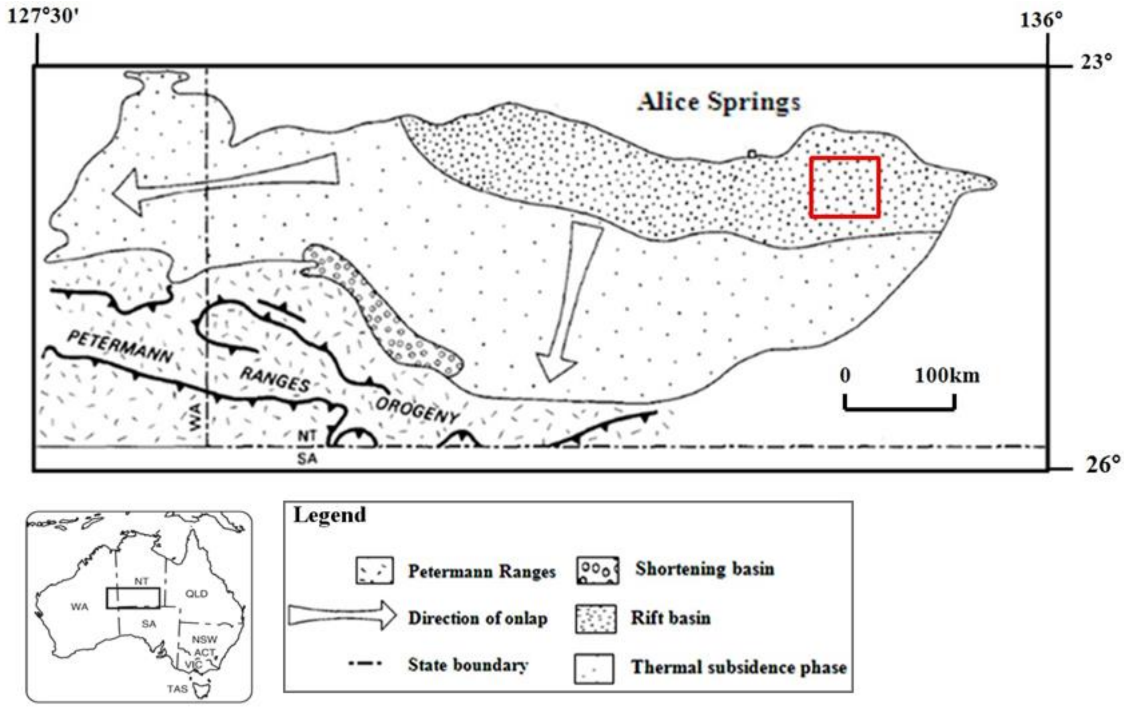


Fig. 3. Distribution of sediments in the Amadeus basin (modified after Korsch & Lindsay, 1989).

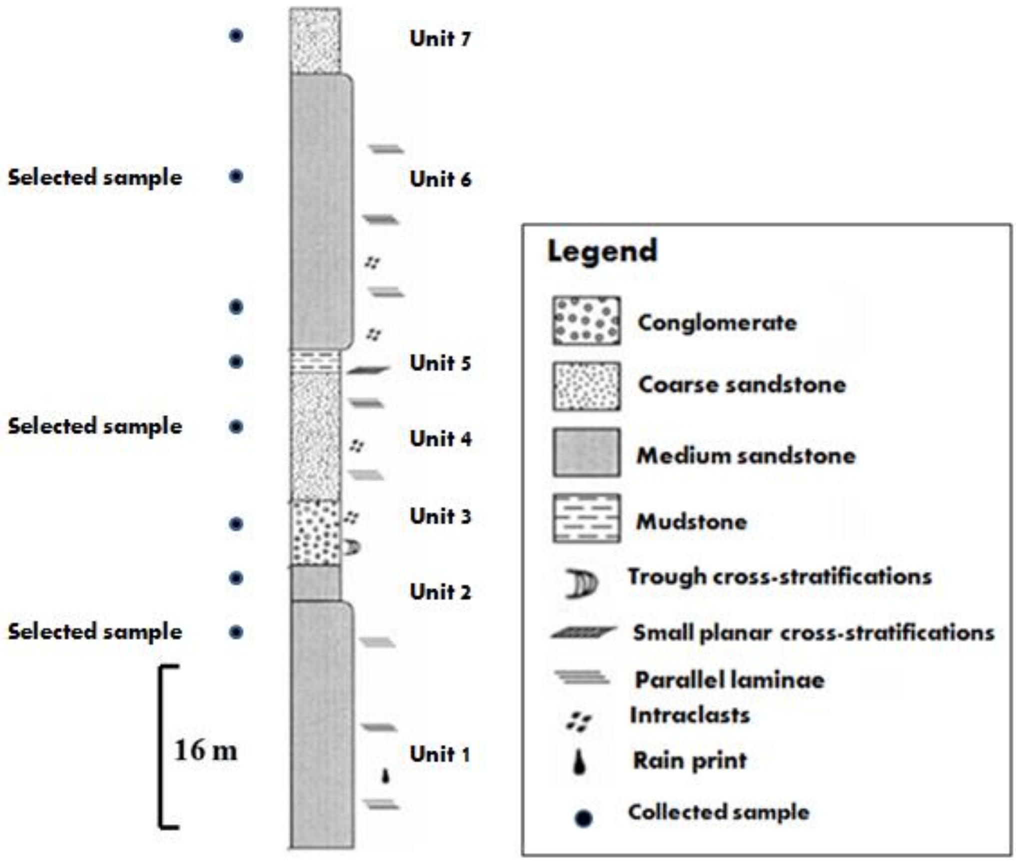


Fig. 4. Sedimentological log of the Heavitree Quartzite shows seven lithofacies.

2. Materials and methods

Three selected samples have been studied petrographically from eight samples were collected from the Heavitree Quartzite section exposed along the Ross River in the northeast of the Amadeus basin (Figs. 4 & 5). Petrographic analysis involves fixing the samples to a glass slides, grinding the sample to 0.003 mm, thick (thin section) and observing to petrographic optical microscope (Olympus BH2) with an attached Olympus digital camera was used to record photomicrographs.

3. Results and Discussions

The microscopic examination indicates that quartz is the most abundant mineral in the Heavitree Quartzite with subordinate feldspar and rock fragments. Tables 1 and 2 show the relative frequency distribution of the main components in the studied formation. The studied samples contain 97 % quartz, in average, suggesting that they are mainly quartz arenites. Fig. 6 shows that quartz is mostly monocrystalline with non-undulatory extinction.

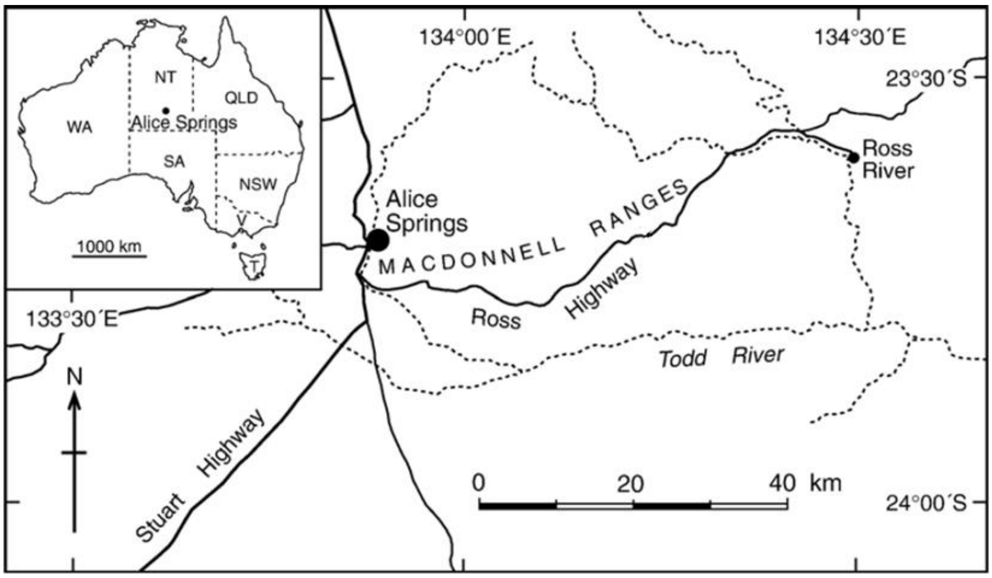


Fig. 5. Map of the MacDonnell Ranges, Northern Territory, central Australia, illustrating the road of Alice Springs to Ross River.

Table 1
Frequency distribution of the main components of the Heavitree Quartzite.

Formation	Unit No.	Qm	Qp	Qt	F	RF
Heavitree Quartzite	1	94.31	2.12	96.43	2.00	1.55
	4	96.00	1.48	97.48	1.39	1.12
	6	94.98	2.24	97.22	1.77	0.98

Table 2
Key for main components used in the present study.

Qm	Monocrystalline quartz
Qp	Polycrystalline quartz
Qt	Total quartz grains (Qm + Qp)
F	Feldspar
RF	Rock fragments

However, polycrystalline quartz grains are also observed in the samples. Quartz grain usually shows non-undulose straighted extinction of granitic origin (Folk, 1980). The polycrystalline quartz was distinguished into two groups: polycrystalline quartz with 2-3 subgrains and polycrystalline quartz with more than 3 subgrains. Orthoclase and anorthite are common feldspars.

The Heavitree Quartzite is well sorted to very well sorted with rounded to well-rounded grains (*see* Fig. 6). Rounding of the grains is difficult to assess because the effects of compaction and cementation have obscured the shape of the original grains. In agreement with Bauluz *et al*., (2000) and Shadan & Hosseini-Barzi (2013) the authors believe that the presence of rounded quartz grains in the studied samples probably indicates long sediment transport. The occurrences of coarse-grained feldspars indicate the prevalent low degree of chemical weathering (Osae *et al*., 2006) in the source area. The occurrence of rounded quartz overgrowths indicates recycling. There are a large number of concavo-convex contacts with some sutured grain contacts. Quartz overgrowth cement has taken place (authigenic cement). Authigenic cement which represents as a black color surrounding quartz grains, which could be an iron oxide rim. There is hematite cement with brown-red color around the quartz grains and hematite cement between quartz grains (Fig. 7).

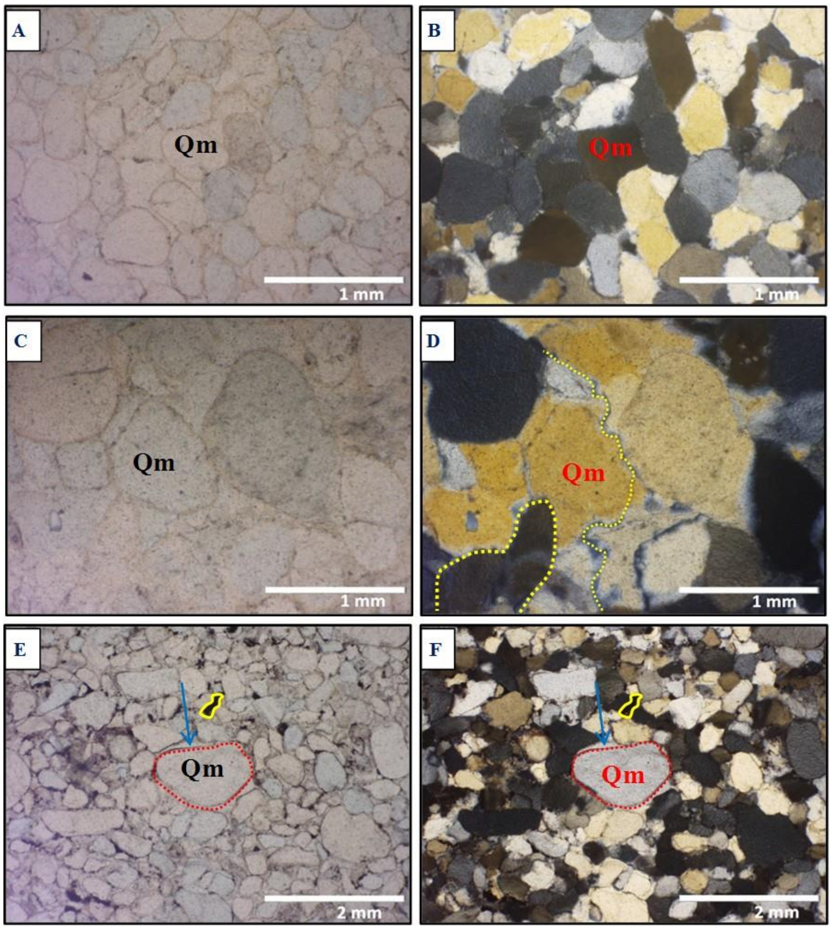


Fig. 6. Photomicrographs (A) and (B) Well rounded, well sorted and well compacted monocrystalline quartz grains (unit 6); (C) and (D) Sutured grain contact. Note all grains are well compacted and there is dissolution due to pressure-solution (unit 4) and (E) and (F) Quartz overgrowth cement (authigenic cement) (unit 1).

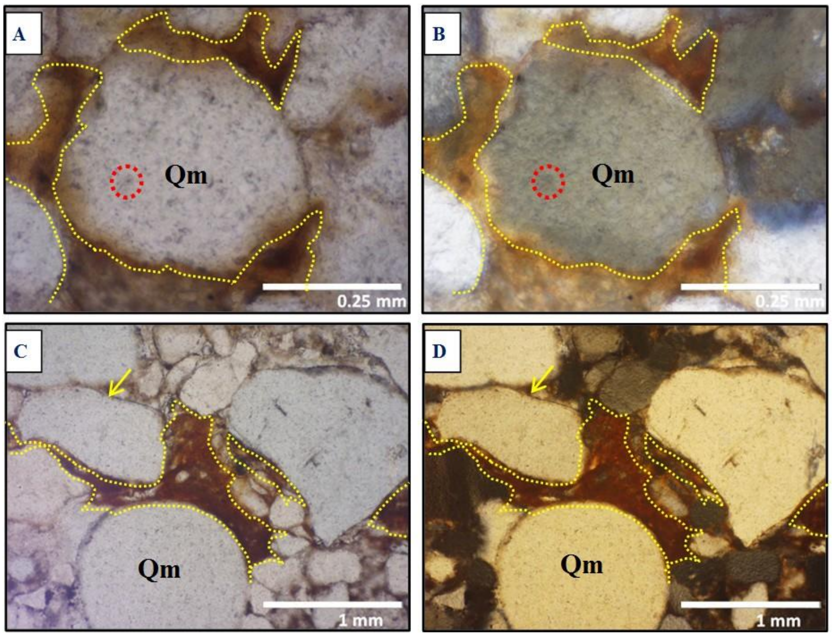


Fig. 7. Photomicrographs (A) and (B) Monocrystalline quartz grains with non-undulatory extinction surrounded by hematite cement (authigenic cement). These quartz grains contains fluid inclusions (unit 1) and (C) and (D) Oversized pore space around well rounded quartz grains due to the dissolution of quartz overgrowth cement, and then filled by hematite cement between quartz grain (unit 1).

There is evidence of diagenetic features that have taken place in the Heavitree Quartzite at different stages. Diagenesis within the Heavitree Quartzite has adversely affected porosity (porosity reduction). The diagenesis in the Heavitree Quartzite could have commenced with early overburden pressure (pressure-solution) being greater than pore fluid pressure, but there is no evidence for grain fracture and breakage.

At many of the contacts between grains, quartz grains have undergone pressure-solution leading to the penetration of one grain by another (concavo-convex contacts). This is the first stage of pressure-solution. When pressure-solution became more intense, the contacts between grains became sutured due to late compaction. However, the degree of compaction is not a function of overburden, but the effect of stress within the rock unit. In this case, the contacts are irregular and wavy because of pressure-solution. This pressure-solution compaction could lead to dissolution of quartz grain and precipitation of silica in form of quartz overgrowth cement (authigenic cement).

The second stage of diagenesis might be dissolution of the quartz overgrowths cement and filled with iron oxide (second authigenic cement) which represents as a black color surrounding quartz grains. There is hematite cements rimmed with brown-red color around the quartz grains. This cement might be due to alteration or replacement of pyrite or biotite to hematite or alternative origin (e.g., Tucker, 2001).

The alteration includes a purely diagenetic mechanism, whereby the iron is supplied by intrastratal dissolution of detrital silicates such as hornblende, augite, olivine, chlorite and magnetite (Tucker, 2001). If the environment is oxidizing due to diagenetic processes, then the iron reprecipitated as hematite or a hydrated iron oxide which possibly converts to hematite on ageing (Tucker, 2001).

3.1. Provenance and tectonic setting

The origin of the Heavitree Quartzite is enigmatic, not only because of its widespread sheet-like distribution and uniformity of composition, but also because intense silicification makes facies studies difficult (Lindsay, 1999). The diagrams of Basu *et al.*, (1975) and Tortosa *et al.*, (1991) show that the data of the studied sandstones fall in the field of granitic source rocks (Fig. 8). The authors believe that the mesoproterozoic granite of Gawler Craton must be the probable source for the Heavitree Quartzite. The tectonic discrimination diagrams (Fig. 9) show that the samples of the Heavitree Quartzite plot in the field of craton interior. Crook (1974) proposed the use of quartz content to infer tectonic setting, and linked quartz rich (>65 % quartz) sandstones to passive continental margins (Atlantic type); intermediate quartz (15–65 % quartz) sandstones to active continental margins (Andean type), and quartz poor (<15 % quartz) sandstones to magmatic island arcs. The Heavitree Quartzite studied here thus corresponds to the Atlantic type sandstones.

3.2. Depositional environment and paleoclimate

The depositional environment of the Heavitree Quartzite was interpreted to be fluvial to shallow marine (Lindsay, 1999). The mineral composition and maturity of the samples suggest that the possible depositional environment of the Heavitree Quartzite is deltaic. The sediments are mineralogically mature and texturally submature to mature due to transport of sediments through a fluvial system to marginal marine. In agreement with Tucker (2001) the authors believe that the hematite cement around the quartz grain suggests that the source of the studied sediments was derived from a continental environment. The climatic discrimination diagrams suggest that the climatic conditions for the source area of the Heavitree Quartzite are humid (Figs. 10 and 11).

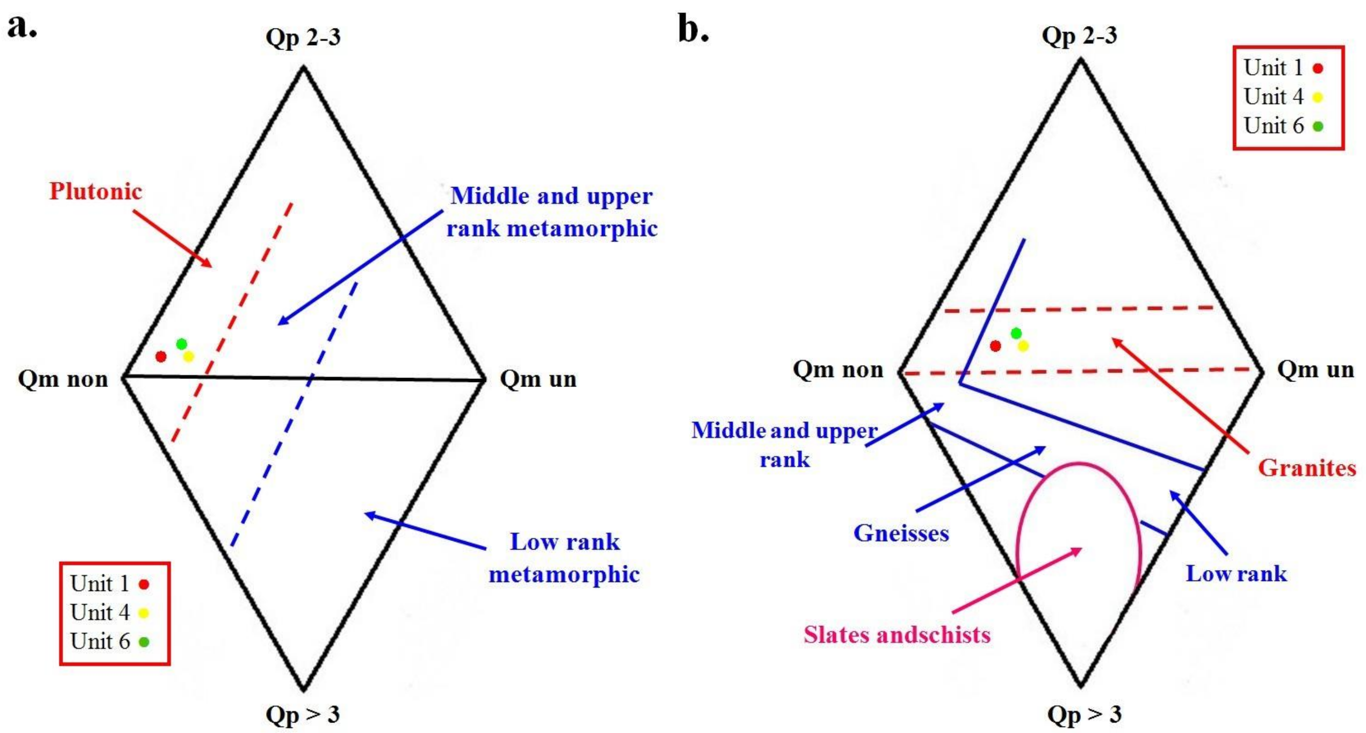


Fig. 8. Varietal quartz diamond plot currently used to discriminate sandstones sourced by different types of crystalline rocks, based on the extinction pattern and polycrystallinity of quartz grains. Qm non = low-undulosity monocrystalline quartz grains; Qm un = high-undulosity monocrystalline quartz grains; Qp2–3 = coarse-grained polycrystalline quartz grains; Qp > 3 = fine-grained polycrystalline quartz grains (fields after Basu *et al*., (1975) and Tortosa *et al*., (1991) (diagrams a and b, respectively).

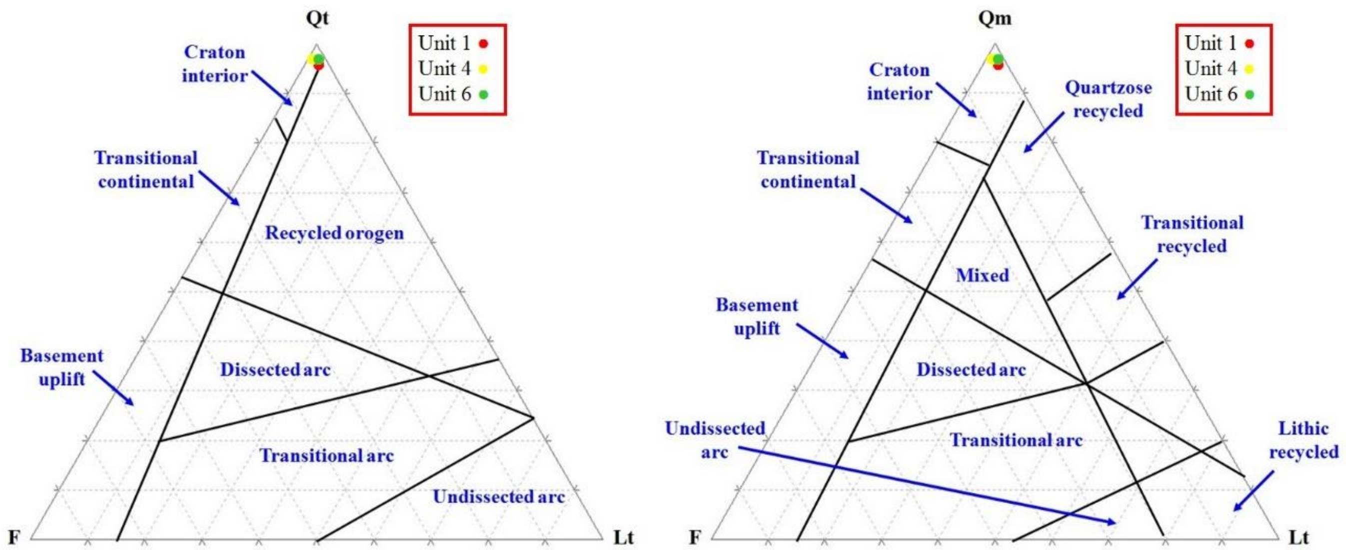
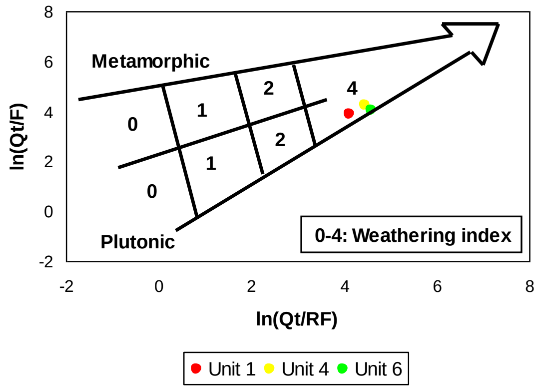


Fig. 9. Tectonic discrimination diagrams of major components for the Heavitree Quartzite (fields after Dickinson *et al*., 1983).



Semi-quantitative weathering index		Physiography (relief): High (mountains) 0	Moderate (hills) 1	Low (plains) 2
Climate (precipitation)	(Semi) Arid and mediterranean 0	0	0	0
	Temperate subhumid 1	0	1	2
	Tropical humid 2	0	2	4

Fig. 10. Climatic discrimination diagram of major components for the Heavitree Quartzite (fields after Suttner and Dutta, 1986).

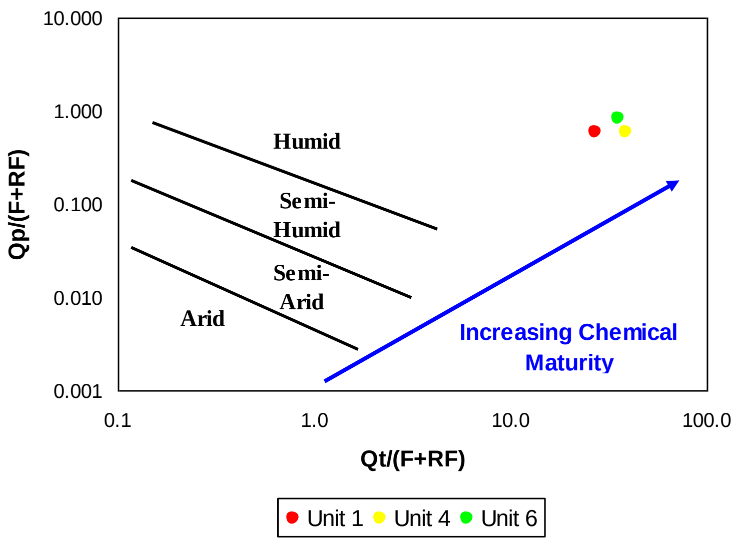


Fig. 11. Climatic discrimination diagram of major components for the Heavitree Quartzite (fields after Suttner and Dutta, 1986).

4. Conclusions

The present paper discusses the petrography of the Heavitree Quartzite from the Amadeus basin, central Australia, with special emphasis on depositional environment, paleoclimate, provenance, and tectonic setting. The studied formation contains 97 % quartz, in average, suggesting that they are mainly quartz arenite. Quartz is mostly monocrystalline with non-undulatory extinction. The Heavitree Quartzite is well sorted to very well sorted with rounded to well-rounded grains. The provenance discrimination diagrams show that granitic rocks are the possible source of the studied formation. The authors believe that the mesoproterozoic granite of Gawler Craton must be the probable source for the Heavitree Quartzite. The tectonic discrimination diagrams show that the studied samples fall in the field of craton interior. The mineral composition and maturity suggest that the possible depositional environment of the Heavitree Quartzite is deltaic. The hematite cement around the quartz grain also indicates that the source of sediments was derived from a continental environment. The climatic discrimination diagrams propose that the climatic conditions for the source area of the Heavitree Quartzite are humid.

Acknowledgements

Very special thanks must be given to Professor Richard Daniel and Dr. Kathryn Amos (University of Adelaide, South Australia) for providing us with their precious ideas and helpful comments. We are deeply grateful to Professors Esam Abdulsamad, Ahmed Al Kawafi and Saad El Ebaidi (University of Benghazi, Libya) for their critical reading and useful suggestions for improving the manuscript. Special thanks also to Andrew Parker (Sydney, Australia) for reading and improving the English style of the text.

References

Basu, A., Young, S., Suttner, L., James, W. and Mack, G.H. (1975) 'Re-evaluation of the use of undulatory extinction and crystallinity in detrital quartz for provenance interpretation', *Journal of Sedimentary Petrology*, 45, pp. 873-882.

Bauluz, B., Mayayo, M.J., Fernandez-Nieto, C. and Gonzalez-Lopez, J.M. (2000) 'Geochemistry of Precambrian and Paleozoic siliciclastic rocks from the Iberian Range, NE Spain: implications for source-area weathering, sorting, provenance, and tectonic setting', *Chemical Geology*, 168, pp. 135-150.

Crook, K.A.W. (1974) 'Lithogenesis and geotectonics: The significance of compositional variation in flysch arenites (greywackes)', *Society of Economical, Paleontological and Mineralogical Special Publications*; 19, pp. 304-310.

Dickinson, W.R., Beard, L.S., Brakenridge, G.R., Erjavec, J.L., Ferguson, R.C., Inman, K.F., Knepp, R.A., Lindberg, F.A. and Ryberg, P.T. (1983) 'Provenance of North American Phanerozoic sandstones in relation to tectonic setting', *Geological Society of America Bulletin*; 94, pp. 222-235.

El Oshebi, F.M. (2017) 'Facies analysis of the Neoproterozoic to Late Cambrian Amadeus Basin, central Australia', *Journal of Science and its applications*; 5(1), pp 16-24.

Folk, R.L. (1980) Petrography of Sedimentary Rocks. Hemphill publishing company, Austin, Texas, p. 184.

Hill, A.C. and Walter, M.R. (2000), Mid-Neoproterozoic (830–750 Ma) isotope stratigraphy of Australia and global correlation. *Precambrian* Research, 100, pp. 181-211.

Korsch, R.J. & Lindsay, J.F. (1989) 'Relationships between deformation and basin evolution in the intracratonic Amadeus Basin, central Australia', In A. Ord (Editor), *Deformation of Crustal Rocks. Tectonophysics*, 158, pp. 5-22.

Lindsay J.F. and Korsch, R.J. (1991) The evolution of the Amadeus Basin, central Australia: In Korsch, R.J. and Kennard, J.M. (editors) Geological and geophysical studies in the Amadeus Basin, central Australia. Bureau of Mineral Resources, Australia, Bulletin, 236, pp. 7-32.

Lindsay J.F. (1999) 'Heavitree Quartzite, a Neoproterozoic (ca 800-760 Ma), high-energy, tidally influenced, ramp association, Amadeus Basin, central Australia', *Australian Journal of Earth Sciences*, 46, pp. 127–139.

Maidment, D.W., Williams, I.S. and Hand, M. (2007) 'Testing long-term patterns of basin sedimentation by detrital zircon geochronology, Centralian Superbasin, Australia', *Basin Research*, 19, pp. 335-360.

Osae, S., Asiedu, D.K., Banoeng-Yakubo, B., Koeberl, C. and Dampare, S.B. (2006) 'Provenance and tectonic setting of Late Proterozoic Buem sandstones of southeastern Ghana: evidence from geochemistry and detrital modes', *Journal of African Earth Sciences*, 44(1), pp. 85-96.

Prichard, C.E. and Quinlan, T. (1962) 'The geology of southern half of the Hermannsburg 1:250,000 sheet. Bu. Min', *Resour. Aust.*, Rep., 61.

Shadan, M. and Hosseini-Barzi, M. (2013) 'Petrography and geochemistry of the Abe Haji Formation in central Iran: implications for provenance and tectonic setting in the southern part of the Tabas block', Revista mexicana de ciencias geologicas, 30(1), pp. 12-34.

Suttner, L.J. and Dutta, P.K. (1986) 'Alluvial sandstone composition and paleoclimate. Framework mineralogy', *Journal of Sedimentary Petrology*, 56, pp. 326–345.

Tortosa, A.; Palomares, M. and Arribas, J. (1991) Quartz grain types in Holocene deposits from the Spanish Central System: some problems in provenance analysis', in Morton, A.C., Todd, S.P., Haughton, P.D.W. (eds.), Developments in Sedimentary Provenance Studies: *Geological Society of London, Special Publication*, 57, pp. 47- 54.

Tucker, M.E. (2001) Sedimentary petrology: An introduction to the origin of sedimentary rocks. Blackwell Scientific Publications, Oxford, London.

Wade, B.P., Hand, M. and Barovich, K.M. (2005) 'Nd isotopic and geochemical constraints on provenance of sedimentary rocks in the eastern Officer Basin, Australia: Implications for the duration of the intracratonic Petermann Orogeny', *Geological Society* of *London*; 162, pp. 513-530.

Walter, M.R., Veevers, J.J., Calver, C.R. and Grey, K. (1995) 'Neoproterozoic stratigraphy of the Centralian Superbasin, Australia', *Precambrian* Research; 73, pp. 173-195.

Wells, A.T., Stewart, A.J. and Skwarko, S.K. (1966) Geology of the south-eastern part of the Amadeus Basin, Northern Territory, Bureau of Mineral Resources, Geology and Geophysics.

Weltje, G.J.; Meijer, X.D. and De Boer, P.L. (1998) 'Stratigraphic inversion of siliciclastic basin fills: a note on the distinction between supply signals resulting from tectonic and climatic forcing', *Basin Research*, 10, pp. 129-153.

Zhao, J.X., McCulloch, M.T. & Bennett, V.C. (1991) 'Sm-Nd and U-Pb zircon isotopic constraints on the provenance of sediments from the Amadeus Basin, central Australia: Evidence for REE fractionation', *Geochim.Cosmochim. Acta*, 56, pp. 921-940.