Note on the Neereno Hill Impact Breccias

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Summary

The Neereno Hill breccias are located north east of the town of Three Springs in Western Australia's Midwest district. The breccias were initially described by Lipple (1982) to have produced by debris flow down steep topography on the Archaean basement of the Yilgarn craton. A literature study and examination of outcrops in the area by the author indicate these breccias may have been produced by a meteorite impact. Note that in the 1980's, little was known about the geology of impact structures.

Outcrops have been provisionally identified in the field to be proximal allochthonous polymict breccia (+/- melt particles), clast-rich to clast-poor impact melts and megabreccias (collectively termed impactites). Interpreted extensive melt sheets indicate a large impact structure of at least 4 km in size. A possible ejecta layer is exposed interbedded with Proterozoic sediments to the west of Neereno Hill and may assist in dating the impact.

The age of the impact is greater than 1200 Ma (Mesoproterozoic) based on the occurrence of NNW-trending cross cutting mafic dykes which are probably part of the Boyagin Dolerite Suite of the Marnda Moorn large igneous province. This would make this impact structure Mesoproterozoic or earlier in age and one of the few recognised Proterozoic impact structures on earth.

There is no topographic expression of an impact crater apart from the elevated areas of possible impact breccia being more resistant to erosion than the surrounding rocks. A study of the aeromagnetic and gravity data does not show any features consistent with an impact structure. Confirmation of an impact site will require petrographic studies and the identification of features unique to impact structures, e.g. PDF in quartz grains.

A field trip was undertaken to the area in early March 2020 to familiarise researchers from Curtin University with the rocks of the area. The party was led by Aaron Carvosie, who is a senior research fellow in the School of Earth and Planetary Science. The group collected samples for examination of their contained zircons and results are pending.

Further work is required to better understand the relationships between the various impact lithologies and those of the Proterozoic and Archaean rocks. There are a number of areas not yet visited and these may add additional valuable geological information.

Introduction

The author has been examining the geology of Western Australia seeking rocks and/or breccia zones that are seemingly out of character to their geological environment, which may represent impact structure deposits or events. The Neereno Hill breccias are a good example of the early results of this study. Other areas in Western Australia have been identified but time has not permitted any follow-up work to date in these other areas (e.g. Doolgunna diamicrites).

The author is a professional geologist with over 40 years of experience in exploration and mining, principally in the search for diamonds, nickel, iron ore and copper. The author is a fellow and registered professional (mineral exploration) of the Australasian Institute of Geoscientists and a member of the Geological Society of Australia and the Meteoritical Society.

The Neereno Hill area is located 280 km north of Perth and 18 km north east of Three Springs and is located on private farmland. Access to the area is via the Midland Highway to Moora, then to Three Springs, then along minor roads to the area.

Figure 1. Location Map for the Neereno Hill impact structure and other impact sites in southern WA (Source Open Street Map)

The location of the breccia outcrops are shown in figure 2.

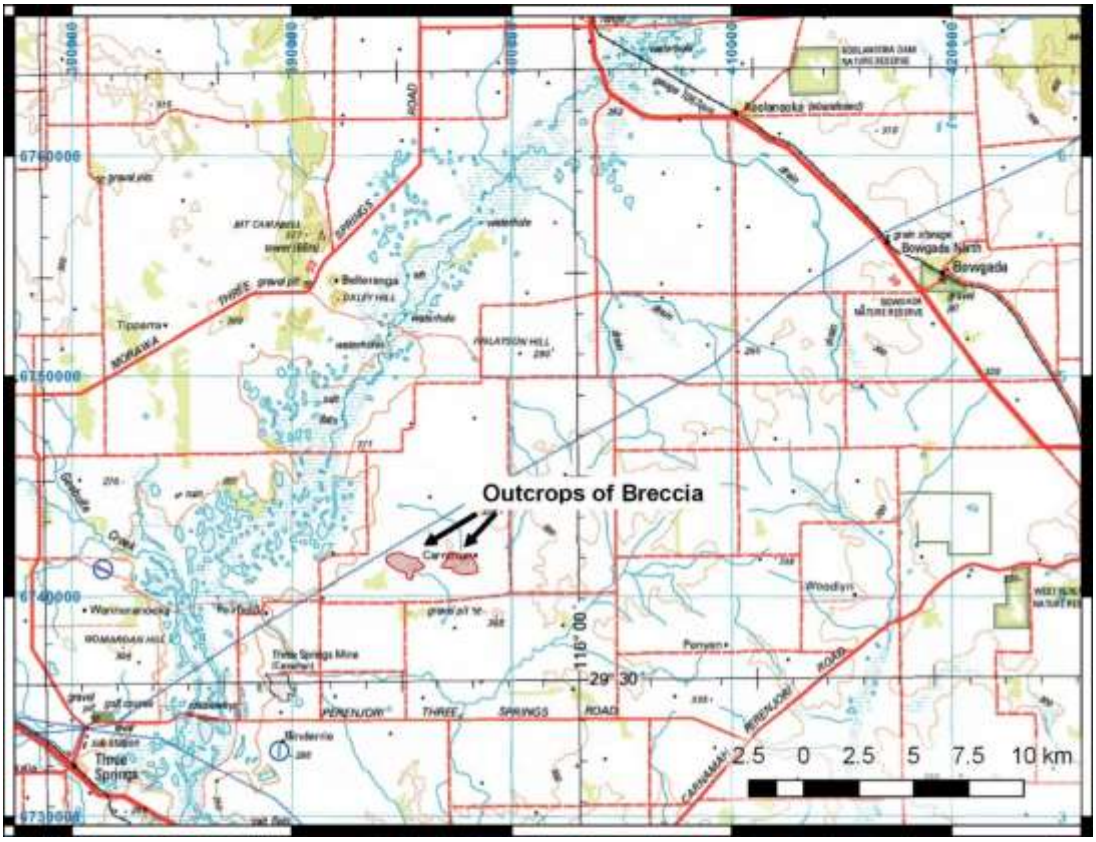

Figure 2. Location Map of the Neereno Hill breccias.

Regional Geology

The Neereno Hill area lies near the western margin of the Archaean Yilgarn craton where the Archaean age granitic gneisses are overlain locally by Middle Proterozoic age Moora Group sediments and volcanics (figure 3).

The "sedimentary breccias" of the Neereno Hill area were first described by Lipple (1984) and were included within the Billeranga Subgroup of the Moora Group (figures 3 and 4). The Moora Group (Mc) is a thin remnant of a formerly extensive platform sequence which unconformably overlies Archaean basement of the Yilgarn Block.

The Archaean rocks of the area comprise granitic intrusives (g4) and granitic gneisses (n4a).

The Moora Group comprises weakly deformed, immature fluvial – alluvial fan – basin margin in its lower part with a significant volcanic or volcanogenic component (the Billeranga Subgroup), and an undeformed, disconformably overlying, mature, upward-fining, siliciclastic-dolomitic, upper part (the Coomberdale Subgroup) (Baxter and Lipple 1985).

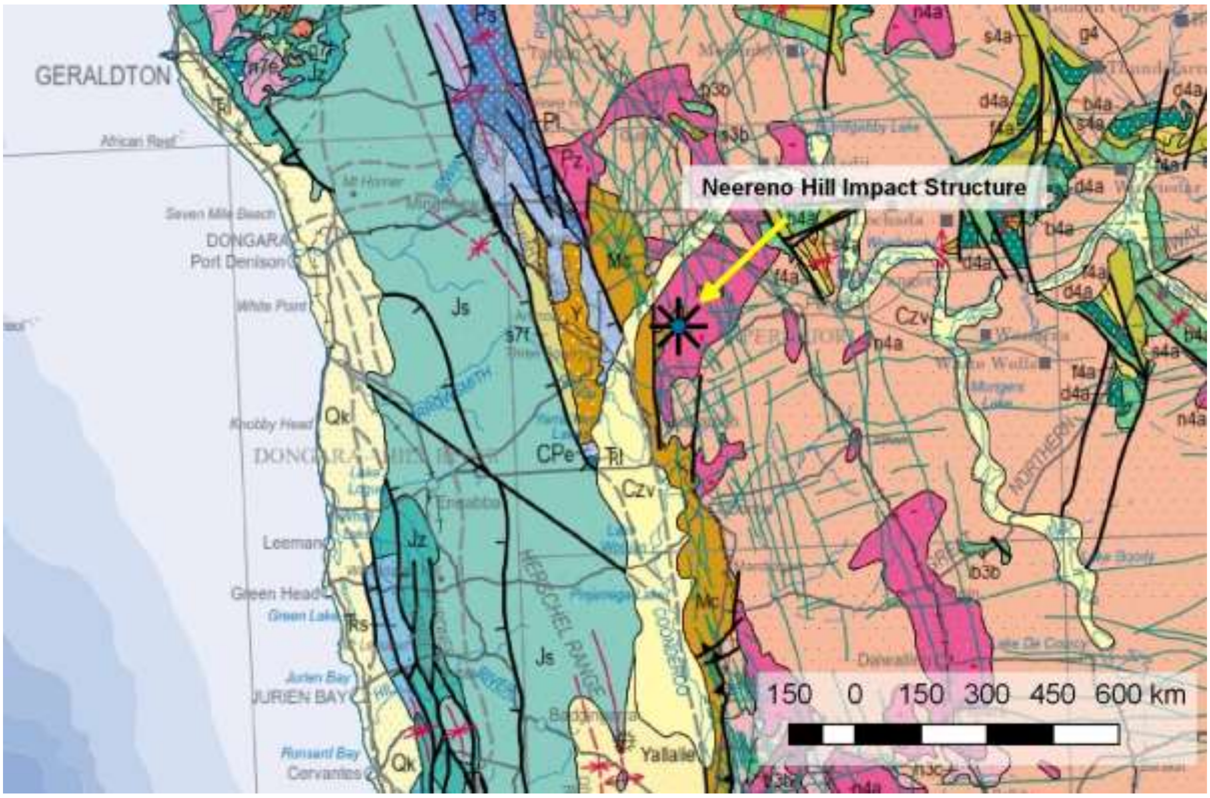

Figure 3. Regional geology in the Three Springs – Perenjori region showing the Neereno Hill Impact Structure, the Moora Group sediments in the brown (map code Mc), the granitic gneiss (n4a, bright pink) of the Yilgarn Block, and Mesozoic (green) and Palaeozoic sediments (blue, CPe, Js, Jz, etc) of the Carnarvon Basin. Geology is from the GSWA Geological Map of Western Australia (2015). Note the Yallallie impact structure located near the southern limit of the figure.

Lipple (1984) described the sedimentary breccia in the Neereno Hill area to have been formed by mass transport in rock avalanches and debris flows from adjacent hilly terrain during the Proterozoic. The author's view is that the breccias are the result of an impact event and are impactites. Note that impact geology was in its infancy at that time and would probably not have been a consideration.

The age of the Moora Group is estimated as mid-Proterozoic based on an imprecise radiometric age date (Compston and Arriens 1968) of 1000 Ma for the Morawa Lavas (Billeranga Subgroup) in the Billeranga Hills (15 km to the north of the Neereno Hill area). The Moora Group appears to be cut by dolerite dykes of the Marnda Moorne dyke suite which are estimated to be about 1200 Ma in age (Wang et al, 2014). This would put an age of the Proterozoic sediments of greater than 1200 Ma.

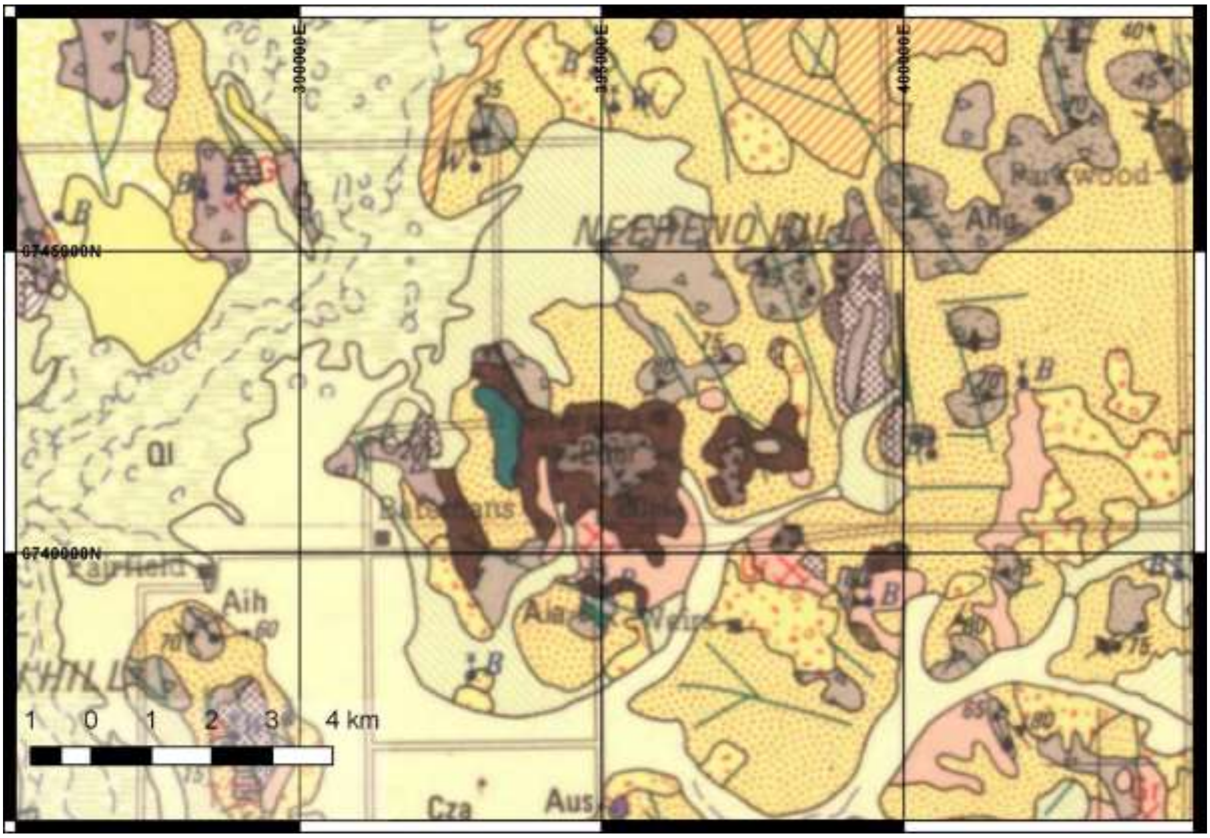

Figure 4. Geological map produced by the GSWA (Perenjori 250k map sheet). PObr are the megabreccias mapped by Lipple.

Field Visit

The Carramar (Hebiton) and Kinyorra farm areas were visited initially by the author in July 2015 to examine outcrops for possible impact features. The paper by Lipple (1984) was used as the base for these initial investigations. His map and geological codes are shown in figures 5 and 6. Numerous short visits have been made to the area since this initial visit.

The farm owners were contacted for permission to visit the areas and their contact details are available on request. The majority of the outcrops occur on the Carramar, Kinyorra and Haeusler farms.

Examination of the outcrops confirmed the observations by Lipple of the presence of significant areas of breccia. The nature of the breccia were very reminiscent to the author of images seen of pseudotachylite, melt rocks and impact breccias from the Vredefort impact structure in South Africa, and outcrops of the Sudbury Breccia seen by the author during a visit to the Sudbury impact structure (Canada).

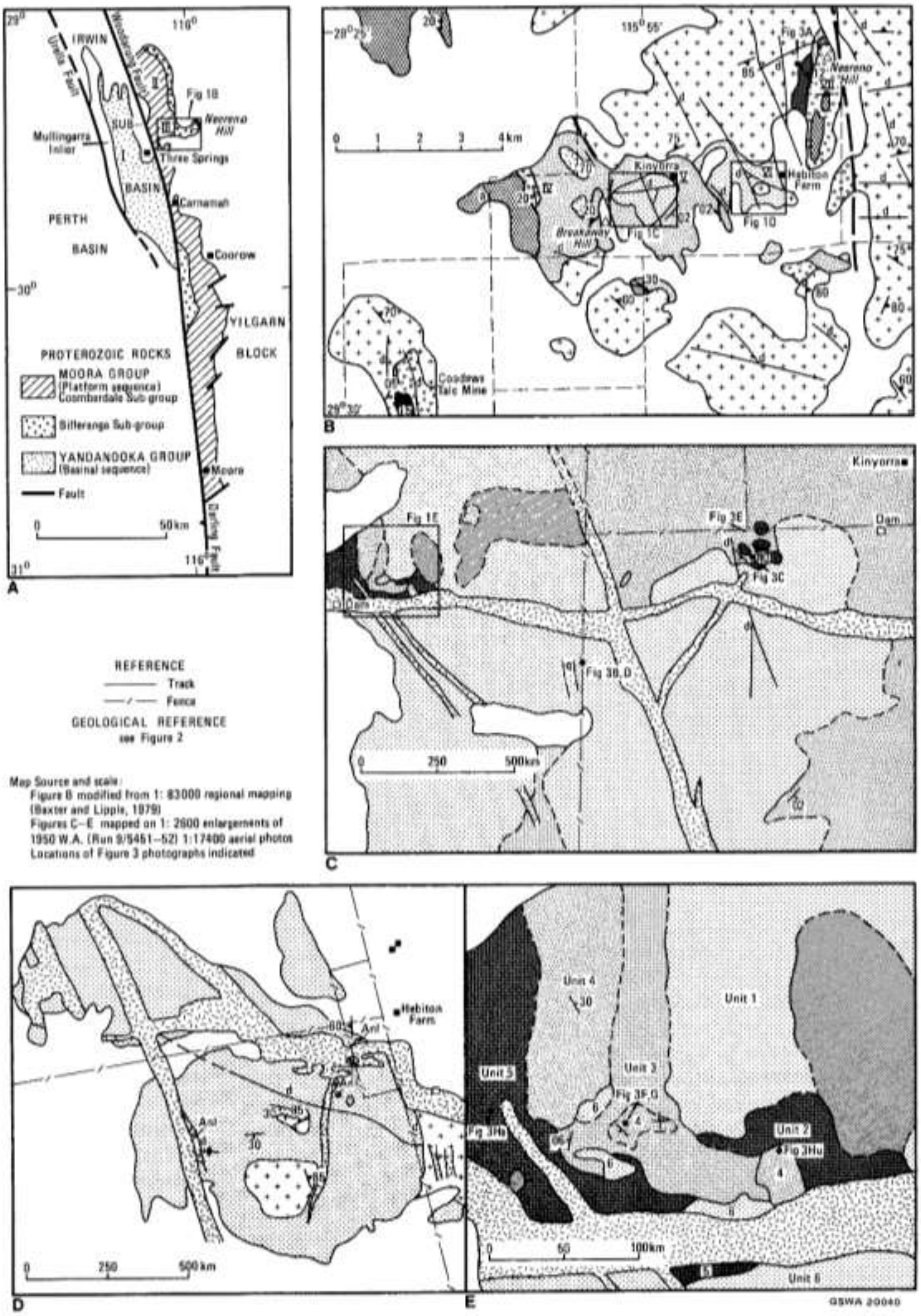

Figure 5. Geological Map from Lipple (1984)

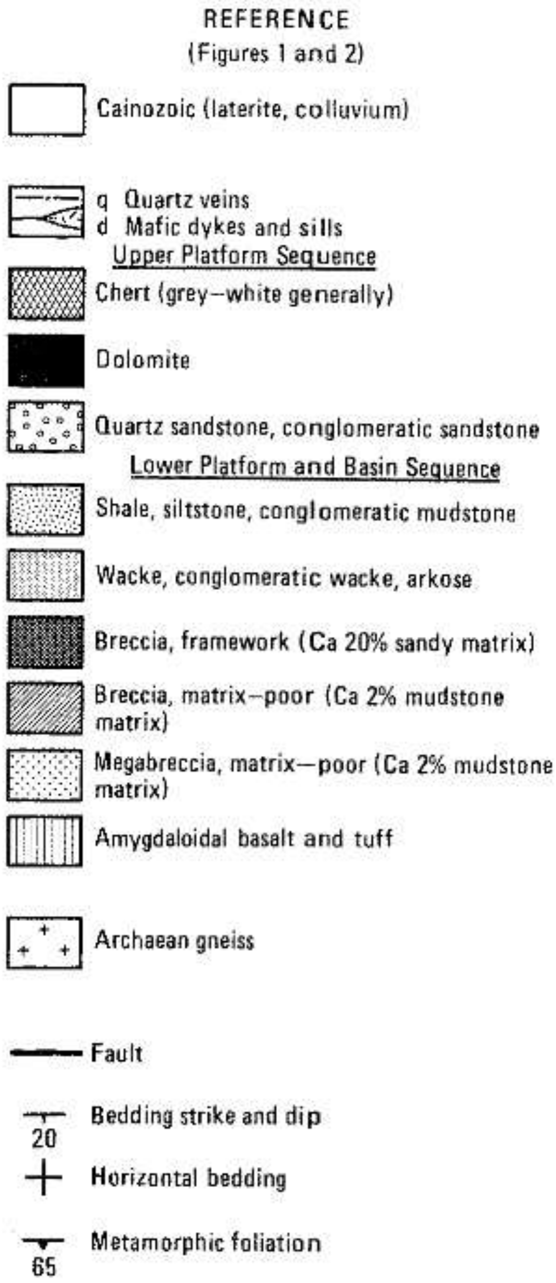

Figure 6. Geological legend for the geological map in figure 1 (from Lipple 1984).

Adjacent areas were also visited to examine the local geology to compare with the proposed impactites.

The coarse and angular nature of the breccia is striking and not a breccia that would normally be associated with fluvial processes. The common occurrence of a very dark green grey fine-grained matrix to the breccia containing entrained angular clasts is very similar to images of pseudotachylites and melt rocks from the Vredefort impact structure in South Africa, and outcrops of the Sudbury Breccia seen by the author in Sudbury Canada.

Field Observations

The breccias occur on two elevated areas, one just west of the Carramar homestead and the other south west of the Kinyorra homestead. The impact rocks occur over an area of at least 4 km east-west and 1 km north-south.

Figure 7. View looking west towards the breccias west of the Kinyorra homestead (GLB_7779).

Figure 8. Typical rubbly outcrop of the breccias, locality GB17, Kinyorra area.

The majority of the breccias appear to by lithic breccia with melt fragments, typically in the upper parts of the exposures with more melt rich breccia and melt rocks appearing at lower levels (Kinyorra area). The breccias are cut by dolerites and a possible hornblende granophyre.

The basement rocks of the area are Archaean granitic gneisses of varying textures and compositions. Locally overlying the Archaean rocks are sediments and volcanics of the Mesoproterozoic Moora Basin. These rocks are best exposed in the Neereno Hill area.

On the western side of Neereno Hill, bedded breccias are exposed underlain and overlain by sandstones (figure 9). It is unclear whether these bedded breccias are reworked impact breccias or perhaps an ejecta blanket formed at the time of impact. If they are an eject blanket, this may allow a better estimate of the age of the impact.

Figure 9. Bedded sedimentary breccias, possible ejecta blanket west of Neereno Hill (GB245, DSC8882)

New Interpretation of the Neerno Hill Breccias

The current interpretation of the Neereno area is that the breccias comprise impactites composed of Archaean Yilgarn block basement rocks.

The revised stratigraphy of the Neereno Hill area is proposed as follows.

Cenozoic laterite, colluvium and alluvial deposits

Proterozoic mafic dykes, Boyagin Dolerite Suite, dolerites (age approximately 1218 - 1202 Ma)

MesoProterozoic – Moora Group (541 – 1600 Ma)
- Coomberdale Subgroup
  - Noondine Chert, stromatolitic
  - Campbell Sandstone, white, cream quartz arenite
- Billeranga Subgroup
  - Morawa Lavas, purple basaltic lavas (1360-1320 Ma), incl Oxley Chert
  - Dalaroo Siltstone, purple siltstone and wacke, well laminated
  - Neereno Sandstone, red purple sandstone, bedded breccias

MesoProterozoic Impactites
- Polymict breccias
- Melt rocks, aphanitic

Archaean, various mixed granitic gneisses (Basement)

A pre-mid Proterozoic impact age is suggested as there are no apparent sedimentary clasts in the impactites and the impactites are cut by the Proterozoic Boyagin dolerite dykes of probable 1200 Ma age.

Stratigraphy of the Impactites

There appears to be a relatively flat-lying stratigraphic sequence in the impactites. The lower-most exposed units are a variety of melt rocks varying from clast poor to clast rich (figures 12 to 15) aphanitic melt rocks. These rocks outcrop along the northern side of the hill to the west of the Kinyorra farmhouse and appear to be at least 10 m thick. The magnetic susceptibilities of these rocks are low at approximately 10 – 20 $x10^{-5}$ SI.

Overlying these melt rocks is a sequence of polymict breccias about 5 m thick with and without melt particles/matrix.

Overlying the melt sheet are more polymict breccias (figures 16 to 21) of at least 10 m thickness but possibly with less melt content than the lower breccia unit.

Cutting these breccias is a dolerite dyke (figure 24) approximately 5 – 10 m wide, with typically medium grain size but with locally chilled top and bottom contacts. This dyke has a low magnetic susceptibility of around 10 – 40 $x10^{-5}$ SI.

A small dyke of possible felsic melt (“granophyre”) occurs running north-south in the Carramar area (figures 25 and 26). It cuts the breccia and also outcrops 1 km to the north. This “granophyre” appears to be associated with a coarser grained dolerite.

Other dolerite dykes of unknown age but of substantial width (20 – 30 m) cut through all the impactite lithologies in NNW orientations. All the impactites and felsic dykes are cut by small dolerite dykes, presumed to be of Proterozoic age.

The dolerite dykes are unfoliated (figure 27) and therefore possibly part of a Proterozoic intrusive event. The dolerite dykes have fine grained contact zones with high magnetic susceptibilities, around 1000 SI and low magnetic susceptibilities in their coarser grained internal parts of about 15 SI.

The narrower more-typical Proterozoic dolerites are typically fine-grained with magnetic susceptibilities of 2000 – 3000 SI (figure 28).

There appears to be three varieties of dolerite intrusives; 1. A typical fine-grained magnetic dolerite running north to north east, 2, medium grained dolerites running east-west and 3, a wider more quartz rich medium to coarse grained variety running NNW.

Discussion

The breccias exposed in the Carramar and Kinyorra areas are polymict breccias with varying amounts of melt contents, containing a variety of granitic and metamorphic rocks, with a matrix of either a dark coloured fine-grained matrix or a matrix of more sandy sized materials. The very fine-grained aphanitic matrix material is interpreted to be impact melt. The relationships between the impact melts and polymict breccias would indicate that the exposures in the Carramar and Kinyorra areas represent the upper parts of the crater fill, as per figure 10.

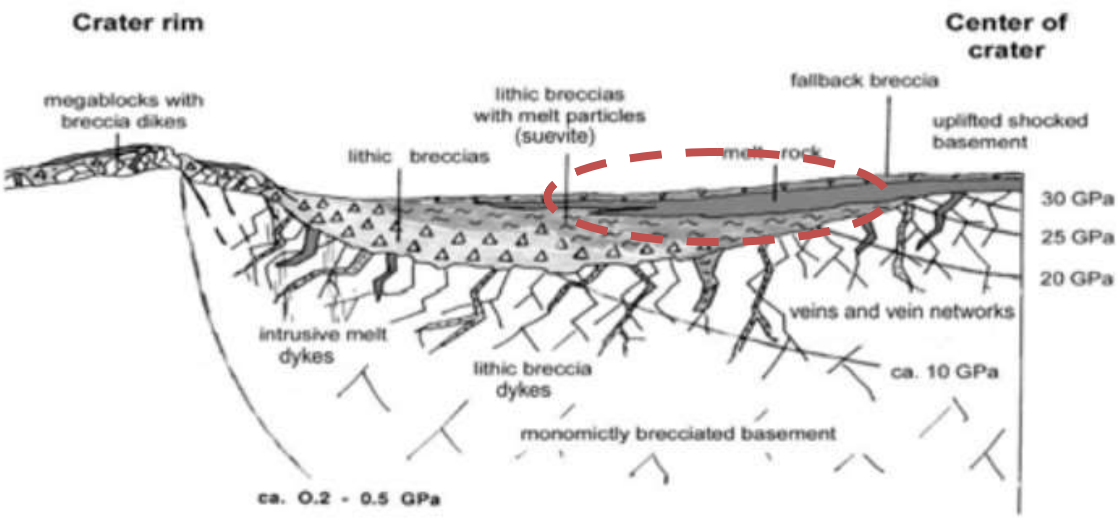

Figure 10. Distribution of impactites in an impact crater (Stoffler and Grieve 2007)

Proterozoic sedimentary clasts appear absent. All rocks are silicified and very competent. The polymict breccia clasts vary in size to about 8 m with the majority in the range of 10 to 50 cm. The clasts are angular to subrounded with the majority being angular.

Aphanitic matrix “layered” rocks are interpreted to be melt rocks and are exposed on the northern and southern sides of the Kinyorra breccia exposures and appears to form an extensive area of horizontal layered melt sheet rocks.

Medium to coarse-grained intrusive rocks (“dolerites”) crosscut the breccias in the Carramar and Kinyorra areas and are medium to coarsely crystalline rocks. These intrusives locally have a grey felspar-phyric magnetic “foliated” contact phase between the intrusive and the breccias. The intrusives are massive and non-foliated and are not part of the Archaean basement. The magnetic susceptibility of these intrusives are typically low (30 -40 x10^{-5} SI) and contrasts to the fine-grained dolerite dykes with high magnetic susceptibilities (1000 – 2000- x10^{-5} SI). These intrusives were originally mapped by Lipple as dolerite.

The lack of Proterozoic sedimentary clasts may be a function of lack of preservation due to the energy of the impact, or that the impact occurred prior to the deposition of the Proterozoic sediments.

The dolerite dykes cut the breccia rocks and are these dykes are probably part of the Boyagin Dolerite Suite, part of the Marnda Moorn igneous event which has been dated at about 1210 Ma (Wang et al 2014) and therefore gives a minimum age of approximately 1200 Ma for the breccias. The Marnda Moorn igneous province occurs over a large part of the Yilgarn craton with NNW dyke trends in the western part of the Yilgarn. The dykes are fine to medium grained dolerites with wide chilled margins with magnetic susceptibilities of 1000 – 2000 x 10^{-5} SI.

The researchers at Curtin collected a number of samples during the March 2020 field trip to examine the samples for zircon grains that may help to understand the genesis and relationships of these rocks.

Conclusions to date are that the Neereno breccias represent polymict impact breccias, with and without melt particles and melt rocks formed by a meteorite impact some time prior to the intrusion of Proterozoic mafic dykes at about 1200 Ma.

Numerous discussions with Peter Haines, Andrew Glikson, Uwe Riewold, Aaron Carvosie, Raiza Raquel Quintero Mendez and Mike Wingate have assisted in the mental wrangling of this area.

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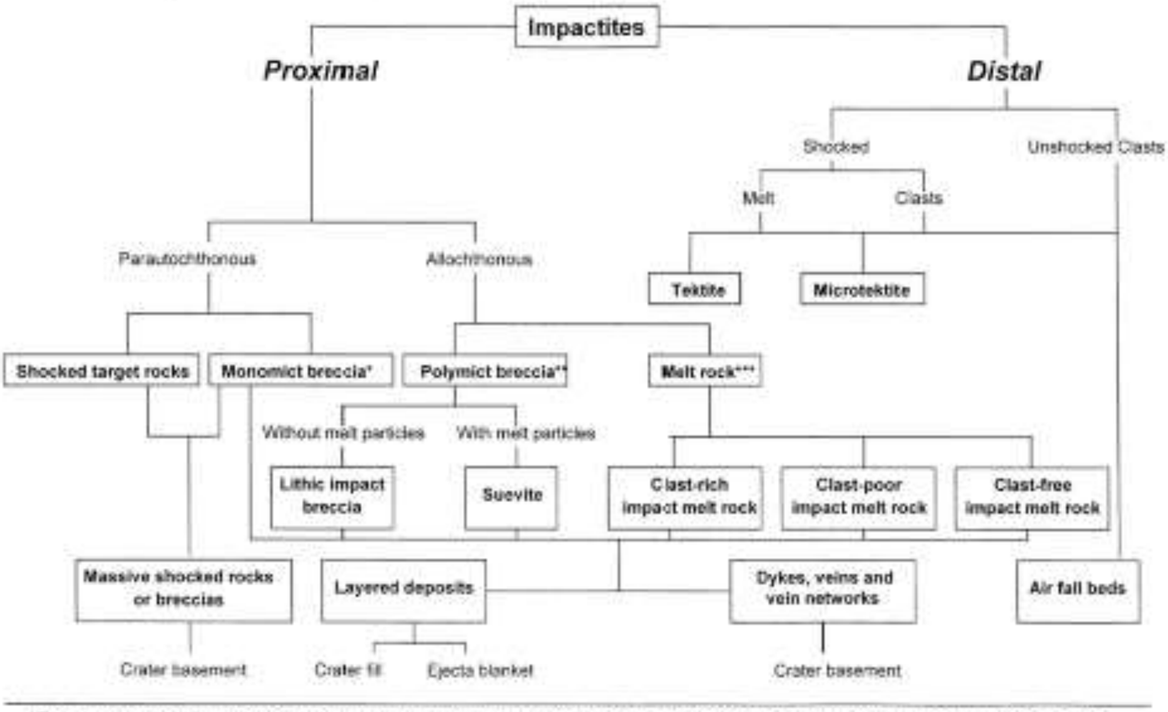
Table 2: Classification of impactites from single impacts according to geological setting, composition, texture, and degree of shock metamorphism (see text for details)



* Typically monomict; **Generally polymict but can be monomict, e.g. in a single lithology target; ***Includes glassy, hypocrystalline and holocrystalline varieties

Figure 11. Classification of Impactites (Stoffler and Grieve 2007)

Impactites

Clast-poor impact melt rock

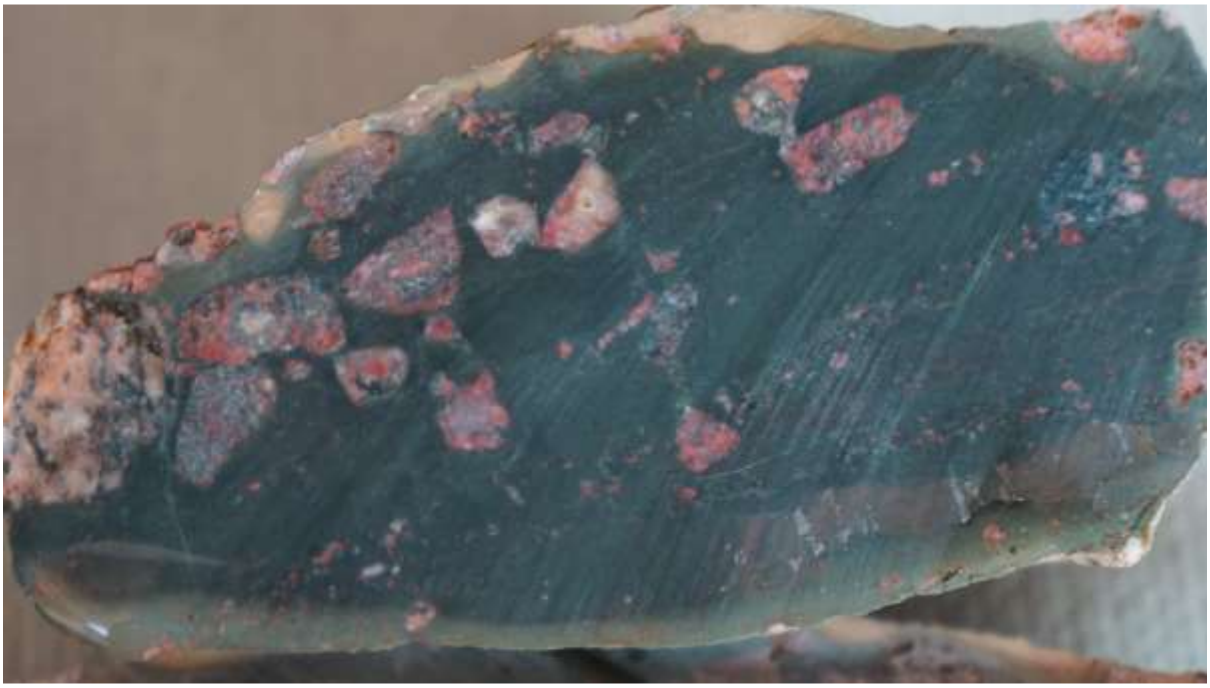


Figure 12. Clast-poor impact melt rock, locality GB16. Width of specimen 6 cm.

Figure 13. Float of clast-rich impact melt, locality GB67, Kinyorra area.

Figure 14. Clast-poor impact melt rock, locality GB141.

Clast-free impact melt rock

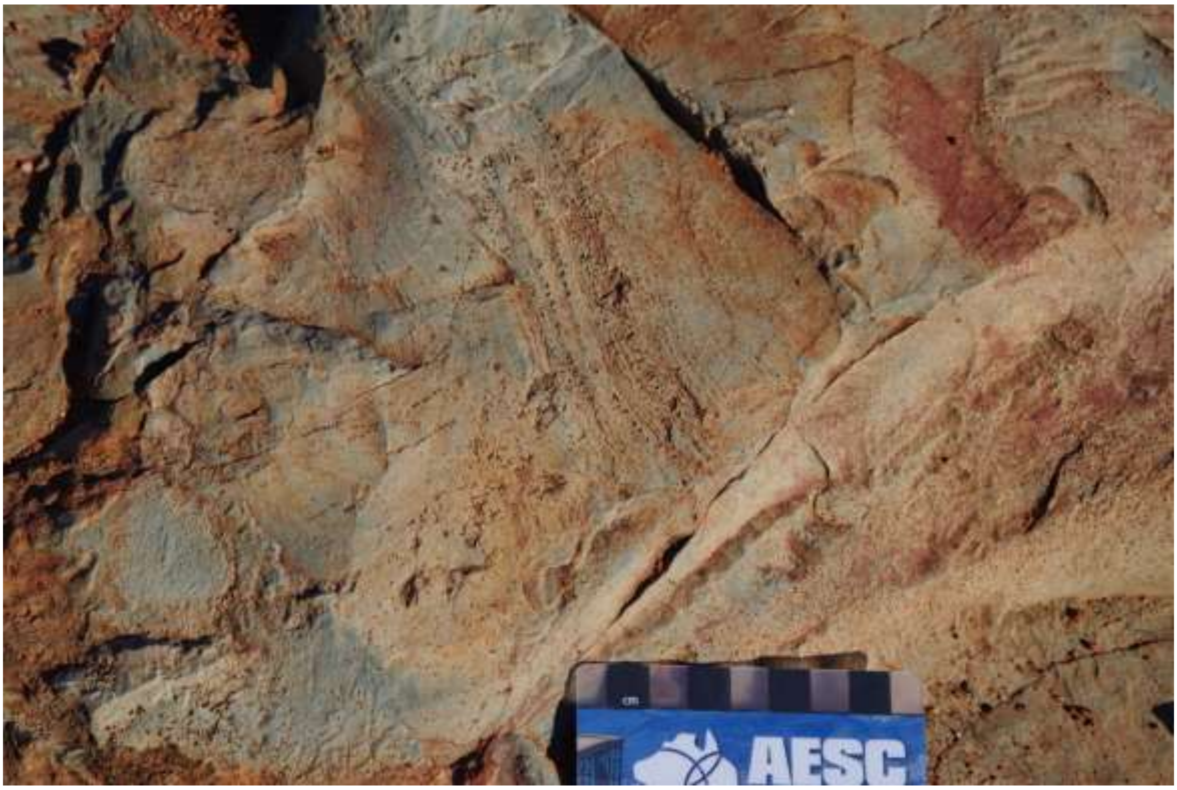


Figure 15. Flow layered clast-poor impact melt, GB141.

Polymict Breccias with Melt Fragments ("Suevite")

Figure 16. Typical polymict breccia, locality GB20, Kinyorra area.

Figure 17. Typical polymict breccia, locality GB08, Carramar area.

Figure 18. Polymict breccia with melt particles, Kinyorra area, locality GB137.

Figure 19. Polymict breccia with pale green melt particles, Kinyorra area, locality GB018.

Clast-rich impact melt rock (Imcr)

Figure 20. Clast-rich melt rock, locality GB08, Carramar area.

Figure 21. Sawn slab of clast rich impact melt from locality GB10.

Figure 22. Float of clast-rich impact melt, locality GB05, Carramar area.

Figure 23. Possible melt rock zone with entrained granitic gneiss clasts, locality GB27, Kinyorra area.

“Diorite” melt Sheet

Fig 24. Outcrop of ?flat-lying diorite(?) sheet at GB230

Impact melt dyke rock (“Granophyre”)

Figure 25. Outcrop of possible felsic melt rock intrusive, “granophyre”, GB39.

Figure 26. Detail of “granophyre”, scale in mm, GB39.

“Diorite” Dykes

Figure 27. “Quartz diorite”(?) dyke with grey granitic gneiss clasts, mag sus 5 – 10 $x10^{-5}$ SI (image 7849, locality GB203)

Dolerite (Pd) Dykes

Figure 28. Outcrop of Boyagin Dolerite Suite dolerite (Pd) at locality GB198, Mag Sus 3000 x 10^{-5} SI (GLB_7842).

Archaean Gneiss Bedrock (Ag)

Figure 29. Outcrops of granitic gneiss (Ag) (basement) at locality GB200 (image GLB_7845)

Proterozoic Moora Group

Coomberdale SubGroup

Noondine Chert (POcc)

Figure 30. Stromatolitic Noondine Chert (GB133, GLB_6130)

Figure 31. Stromatolitic Noondine Chert (GB133, GLB_6134)

Campbell Sandstone (POcz)

Figure 32. Campbell Sandstone, near summit of Neereno Hill (GB253,DSC8887)

Figure 33. Campbell Sandstone, coarse grained (POcz)(GB253, DCS8888)

Figure 34. Campbell Sandstone (POcz) (approx. 399260mE, 6743780 mN, GLB_6136)

Billeranga SubGroup

Oxley Chert (PObc)

Figure 35. Oxley Chert (PObc), north of Neereno Hill (GB249, DSC8884)

Morawa Lavas (PObb)

Figure 36. Morawa Lavas exposed near Mount Campbell (GB136, GLB_6142)

Dalaroo Siltstone (POnb)

Figure 37. Dalaroo Siltstone exposed to the west of Kinyorra (PObn) (GB131, IMG_3388)

Nareeno Formation (PObr)

Figure 38. Red – purplish sandstone, Neereno Formation (PObr) (GB240, DSC8873)

Figure 39. Bedded breccias, Neereno Formation (PObr) (GB241, DSC8874)

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