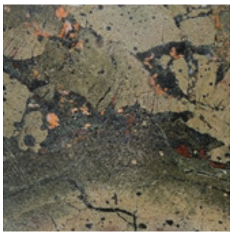
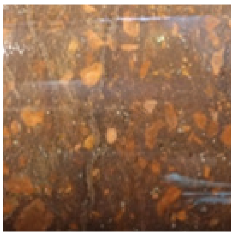
Report on Mineral Systems Drilling Program drillhole MSDP03, Six Mile Hill area

Carol Simpson

Report Book
2017/00024

SOUTH AUSTRALIA

Government of South Australia
Department of the Premier and Cabinet

Report on Mineral Systems Drilling Program drillhole MSDP03, Six Mile Hill area

Carol Simpson

Geological Survey of South Australia
Resources and Energy Group
Department of the Premier and Cabinet

August 2017

Report Book 2017/00024

Resources and Energy
Department of the Premier and Cabinet
Level 7, 101 Grenfell Street, Adelaide
GPO Box 320, Adelaide SA 5001
Phone +61 8 8463 3037
Email dpc.minerals@sa.gov.au
www.minerals.dpc.sa.gov.au

South Australian Resources Information Gateway (SARIG)
SARIG provides up-to-date views of mineral, petroleum and geothermal tenements and other geoscientific data. You can search, view and download information relating to minerals and mining in South Australia including tenement details, mines and mineral deposits, geological and geophysical data, publications and reports (including company reports).
map.sarig.sa.gov.au

Preferred way to cite this publication
Simpson C 2017. *Report on Mineral Systems Drilling Program drillhole MSDP03, Six Mile Hill area*, Report Book 2017/00024. Department of the Premier and Cabinet, South Australia, Adelaide.

CONTENTS

FIGURES

Report on the Mineral Systems Drilling Program drillhole MSDP03, Six Mile Hill area

Carol Simpson

ABSTRACT

MSDP03 (287997) is one of four diamond drillholes drilled in the Six Mile Hill area as part of the Mineral Systems Drilling Program (MSDP) in 2015. The hole was drilled to 262.6 m depth and intersected two units from the lower part of the Mesoproterozoic Gawler Range Volcanics, comprising a 'felsic volcanic unit' (10.3-102.2 m), and a 'mafic volcanic unit' (102.2-262.6 m). This report includes a graphic log, description and interpretation of the main geological features of the lower GRV units in MSDP03, based on detailed logging of both the physical drill core and high resolution core images, as well as thin section petrological observations.

The 'felsic volcanic unit' is a massive, homogeneous, relatively crystal-rich (25-39 modal %) dacite, which contains phenocrysts of mainly plagioclase and subordinate replaced ferromagnesian minerals, alkali feldspar and rare quartz set in an originally glassy groundmass. A weak flow foliation occurs near the base of the unit, which is also finely amygdaloidal and weakly brecciated. The dacite is regarded as a coherent body emplaced as a single unit but in the absence of the upper contact, could be either a lava flow or high-level sill.

The 'mafic volcanic unit' comprises 6 mainly aphyric basalt flow units, ranging in thickness from 17-31 m. Many of these flow units have oxidised tops marked by patchy development of abundant small amygdales, which have been interpreted as probable flow-top breccia. The sequence also includes a 16 m-thick interval which consists of lengths of coherent basalt to 1 m, which are separated by intervals (to >1 m) of dark, fine monomictic breccia. The boundaries between the basalt and breccia are smoothly curved and dark. This interval has been interpreted as a mixed breccia composed of small pillows or pillow fragments with a hyaloclastite matrix. The base of the mafic volcanic sequence is marked by normally graded pebbly to fine-grained volcaniclastic sandstone, which in thin section, contains a significant amount of felsic volcanic grains.

INTRODUCTION

This report summarises the geology intersected in drillhole MSDP03 (287997), one of four holes drilled in the Six Mile Hill area as part of the Mineral Systems Drilling Program in 2015 (Fabris *et al.*, 2017). Drillhole MSDP03 is a vertical hole collared at 723300.569E 6406055.816N in the Six Mile Hill area, which is situated in the north-eastern part of the Eyre Peninsula between Port Augusta in the east and Iron Knob in the west (Fig.1). It is located on "Illeroo" property, approximately 2 km south of Nine Mile Dam. For a description of the geology of the Six Mile Hill area the reader is referred to McAvaney *et al.* (2016), as well as the associated 1:75 000 scale surface geology (Krapf *et al.* 2016) and interpreted bedrock geology maps (Pawley *et al.* 2016).

MSDP03 was drilled to 262.6 m depth as diamond core and intersected two units from the lower part of the Mesoproterozoic Gawler Range Volcanics (referred to herein as lower GRV); a felsic volcanic unit (described as Spearfelt Rhyodacite in McAvaney *et al.* 2016) and a mafic volcanic unit (Roopena Basalt in McAvaney *et al.* 2016).

This report describes the main geological features of the felsic and mafic units in MSDP03 and provides an interpretation of the features observed in this drillhole. The report also includes a graphic log (Appendix I) and accompanying log notes (Appendix II) and petrographic descriptions of six samples from the hole (Appendix III). Photos of the main textural and compositional features of the core are included in this report, and all the core photographs captured during this study are accessible via the South Australian Resources Information Gateway (SARIG) https://map.sarig.sa.gov.au, by using the drillhole search function. A similar report has been produced for MSDP01 (287995) (Simpson, 2017a) and MSDP04 (287998) (Simpson, 2017b).

Discussion of the significance of the findings described in this report in a more regional context, including emplacement processes, depositional environment and palaeogeographic interpretation of the lower GRV, as well as the geochemical signature of the lower GRV rocks, are the subject of a third report (Simpson, 2017c) entitled *Interpretative Report on the lower Gawler Range Volcanics in the Six Mile Hill area*.

The observations described in this report were made during a two-step process involving initial scrutiny of core at rig digital photographs and high-quality Hylogger digital photographs and construction of a detailed log of the drillhole. The second phase was carried out at the South Australian Drill Core Reference Library at Tonsley, Adelaide, where the drill core was closely inspected to verify initial photo observations. Reference and thin samples were collected as required. Final drill-log compilation was carried out using the verified logs and petrographic confirmation of some lithologies, in addition to other data sets such as whole rock geochemistry, Lab-at-Rig geochemistry, down-hole geophysics and Hylogger data.

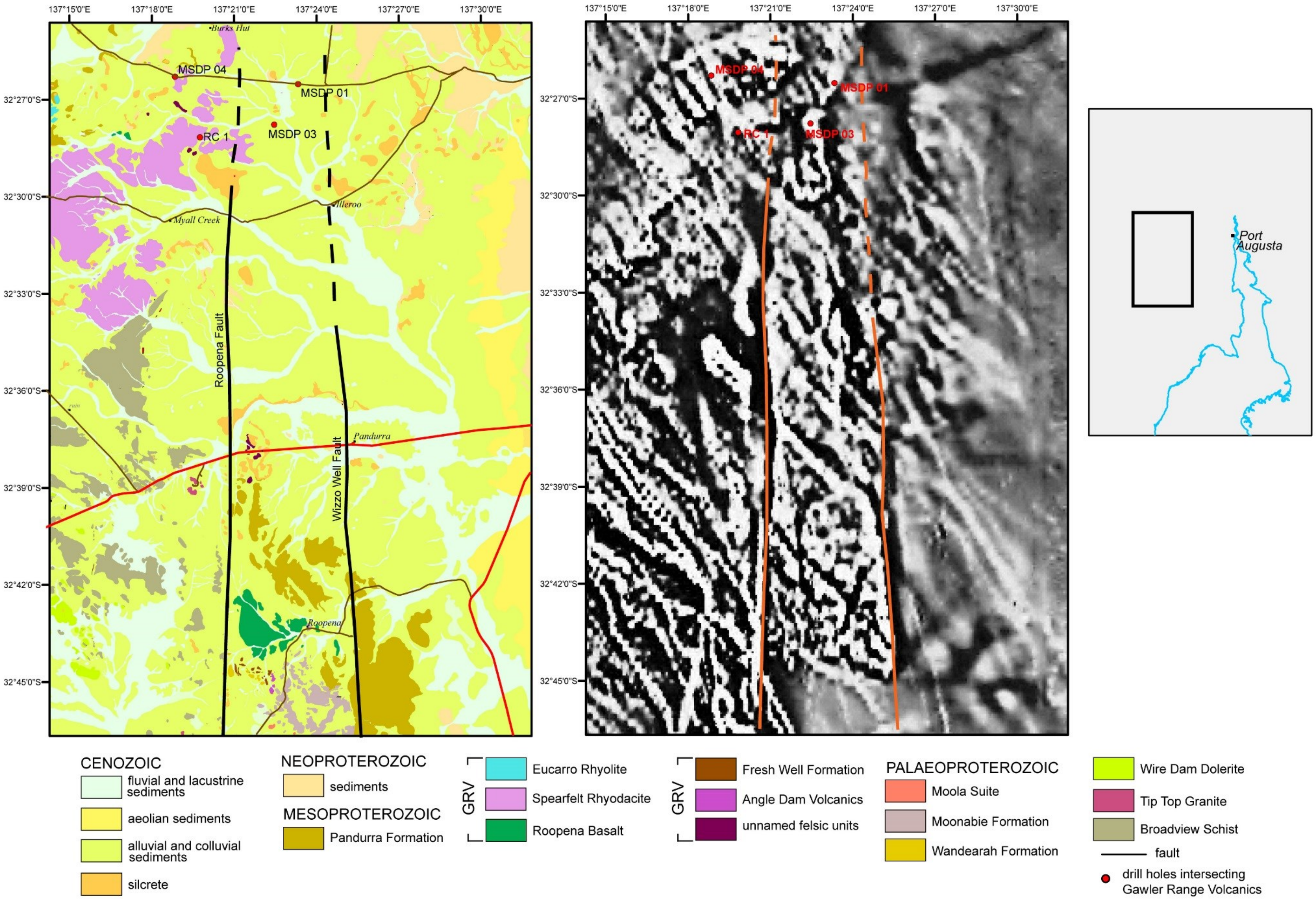


Figure 1. Location map showing the position of drillhole MSDP03 in the Six Mile Hill area. Simplified from Krapf *et al.* (2016).

GEOLOGY INTERSECTED IN MSDP03

The upper 10 m of the drillhole intersected a small amount of Quaternary cover (to ~1.3 m) and in situ regolith/saprolite related to the underlying felsic volcanic unit. These deposits are not described further in this report.

FELSIC VOLCANIC UNIT

Recognisable felsic volcanic unit was intersected between 10.3 m and 102.2 m. In MSDP03, it is an essentially homogeneous, moderately crystal-rich, plagioclase-phyric coherent felsic volcanic rock (Fig. 2). It is pink in colour near the surface, darkening to a brick red/brown colour for most of the unit. The entire unit has undergone hematite alteration and fine fracturing, the latter resulting in significant zones of finely broken core throughout (see Appendix II).

In the more weathered upper part of the hole, the felsic volcanic unit has a visually estimated feldspar (mainly plagioclase) phenocryst content of ~15-20 modal %, mostly to 2-3 mm grainsize. Plagioclase abundance and size increases slightly with depth, with much of the unit containing >20 modal % phenocrysts, mainly to 5 mm in size but including a small number of euhedral plagioclase crystals to 10 mm. Plagioclase phenocrysts were visibly less abundant and smaller in the basal 20-30 cm of the unit. Visible quartz phenocrysts are exceedingly rare throughout the unit but range in size to 8 mm. The quartz content in MSDP03 is noticeably lower than the upper felsic volcanic unit in either MSDP01 or MSDP04, which contain trace but conspicuous quartz phenocrysts throughout the preserved intervals. Minor, fine-grained altered ferromagnesian minerals are only evident in the least altered parts of the core.

In thin section, three samples from the lower half of the unit are described in Appendix III and are very similar to one another. The estimated phenocryst content (~25-30 modal %) is slightly higher than it appears in core. The thin sectioned samples contain ~20-23 modal % feldspar, most of which is sericite- and hematite-altered and albitised plagioclase, however there is a small amount of more altered probable alkali feldspar. The feldspar phenocrysts are typically tabular with euhedral/subhedral boundaries, in some slightly embayed. These phenocrysts are mainly <6 mm in length but isolated larger phenocrysts are up to 10 mm. Chlorite-carbonate-iron oxide-altered ferromagnesian phenocrysts are <1-2 mm in size and based on a few well-preserved shapes, may have originally been pyroxene. Quartz occurs only in accessory amounts as embayed phenocrysts to 3 mm and microphenocrysts. Bladed apatite crystals to 1.5 mm are a conspicuous accessory mineral and rare zircon was observed. The groundmass is mainly massive and consists of a granophyric intergrowth of altered feldspar and interstitial quartz but retains a blotchy micropoikilitic texture indicative of slow devitrification of glass (Fig. 3).

Figure 2. Core photograph showing the evenly porphyritic texture (mostly plagioclase and minor small altered ferromagnesian minerals) of the felsic volcanic unit from 85.7 m depth.

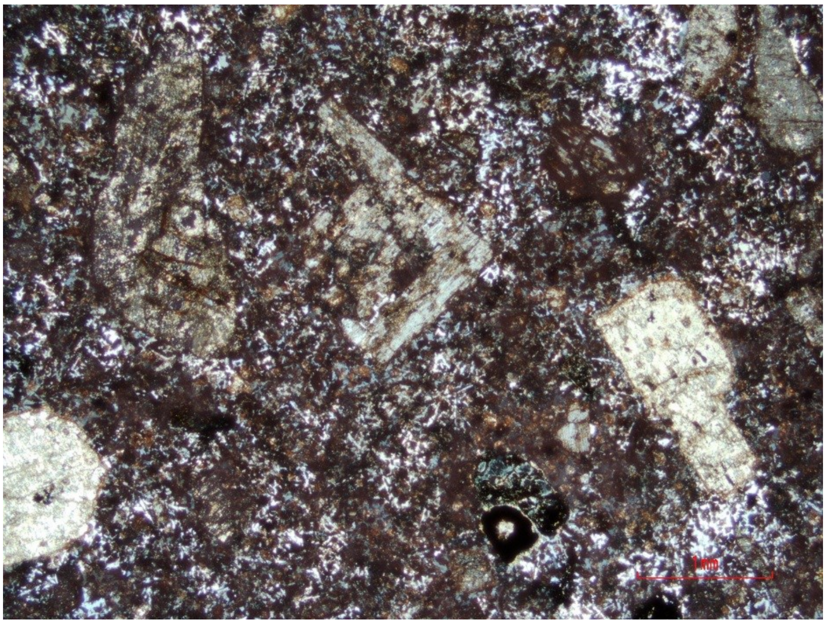


Figure 3. Photomicrograph in cross-polarised light of the overall porphyritic texture of the interior of the felsic volcanic unit in MSDP03 at 50.8 m depth. The phenocrysts are altered plagioclase and a small chlorite-replaced ferromagnesian mineral at centre base of photo (next to opaque). The blotchy texture in the granophyric quartz-feldspar groundmass is micropoikilitic texture. X 2 lens, base of photo is 6 mm. (Sample 2332877).

The majority of the unit has a massive texture, however, below 91 m, a weak planar flow fabric defined by tabular plagioclase phenocrysts and a faint foliation in the groundmass, was observed (Fig. 4). A thin section from this level (Appendix III) shows that this faint flow-banding is defined by discontinuous narrow bands of fine alteration minerals (chlorite, clays, hematite) within the normal granophyric groundmass. Fine brecciation was sporadically observed in the lower part of the dacite, from ~95 m depth to the base (Fig. 5) and this part of the unit also contains small irregular quartz-filled amygdales. The breccia is generally not well-preserved, however, appears to be monomictic and composed mainly of angular blocky dacite clasts that are mostly mm- and cm-scale. Finer grained pale coloured material between the larger and/or more obvious clasts appears to be the same composition as the clasts but includes secondary quartz. The origin of the breccia remains uncertain but is most likely to be an autobreccia. The contact between the felsic volcanic unit and top of the underlying mafic volcanic unit appears to be sharp and planar.

The felsic volcanic unit in MSDP03 is an undifferentiated single unit, which apart from subtle increase in phenocryst size and abundance, is essentially homogeneous over its approximately 100 m thickness. It lacks features usually associated with an ignimbritic origin, instead being characterised by an evenly porphyritic texture and euhedral/subhedral phenocrysts that occur within an originally glassy groundmass, which has devitrified to a micropoikilitic texture. The lower part of the dacite is weakly flow-banded, brecciated and amygdaloidal and sits on the underlying mafic volcanic unit with a sharp, planar contact but in the absence of an upper contact, it is not possible to distinguish whether the felsic volcanic unit was emplaced as a lava flow or as a high-level sill.

Figure 4. Core photograph showing flow foliation that is defined by paler folia in the groundmass and some alignment of plagioclase phenocrysts from 93 m depth.

Figure 5. Core photograph showing brecciation in the lower part of the felsic volcanic unit (95.1 m depth) and the occurrence of small quartz-filled amygdales.

MAFIC VOLCANIC UNIT

In drillhole MSDP03, 160.4 m of the mafic volcanic unit has been intersected. Within this interval, six aphyric to very sparsely plagioclase-phyric basalt lava flows, a thick predominantly monomictic breccia and a small amount of graded volcaniclastic sandstone/siltstone at the end of the drillhole (Appendix I) have been delineated. It is feasible that additional basalt flows may exist with margins obscured in zones of broken core.

The six coherent basalt flow units range in thickness from ~17 m to 31 m and have been delineated by a variety of features including amygdale abundance and size, basalt colour, occurrence of breccia and to a much lesser extent by variation in phenocryst abundance (see Appendixes I and II). In thin section (sample 2332881 from a monomictic basalt breccia), the basalt is sparsely plagioclase-phyric, containing a few (2-3 modal %) albitised plagioclase phenocrysts to 3.5 mm in length and a second thin section, sample 2332882, is aphyric. Both consist of abundant hematite-stained, ex-ferromagnesian minerals (most likely small clinopyroxene grains) with a grainsize of 0.1-0.2 mm, which sub-ophitically enclose bladed albitised plagioclase microphenocrysts, which range from <0.1 to 0.4 mm in length and have hollow cores or swallowtail terminations, both indicative of rapid cooling (Fig. 6).

The flow tops of the six identified flow units are amygdaloidal in the upper 1 to 6 m of the basalt and typically blotchy red/brown to green in colour, reflecting increased hematite and chlorite alteration in the upper vesicular parts of the flows. The majority of the amygdales are oval in shape and range from <1-2 mm to 10 mm diameter and are mainly chlorite-filled but a minority are pink or white in colour (probably albite and quartz/carbonate). Regardless of size, amygdale content rarely exceeds 20 modal % in the upper parts of flows. Several of the delineated basalt flow units (units 3, 4 and 5) display a patchy development of amygdale abundance and size (Figs 7 and 8) at a scale of a few cm to 20 cm in the upper few metres of the flow. Boundaries between patches of different vesicularity vary from diffusely- to well-defined and are generally smoothly curved to indented. The diffusely-defined patchy texture near the tops of flow units is considered most likely to represent the scoriaceous irregular to rubbly top of the flow (flow-top breccia). Some of the boundaries are better-defined and have 1 cm-wide very fine dense bands (see Fig. 8), which may indicate chilling and these features are suggestive of the margins of pillows.

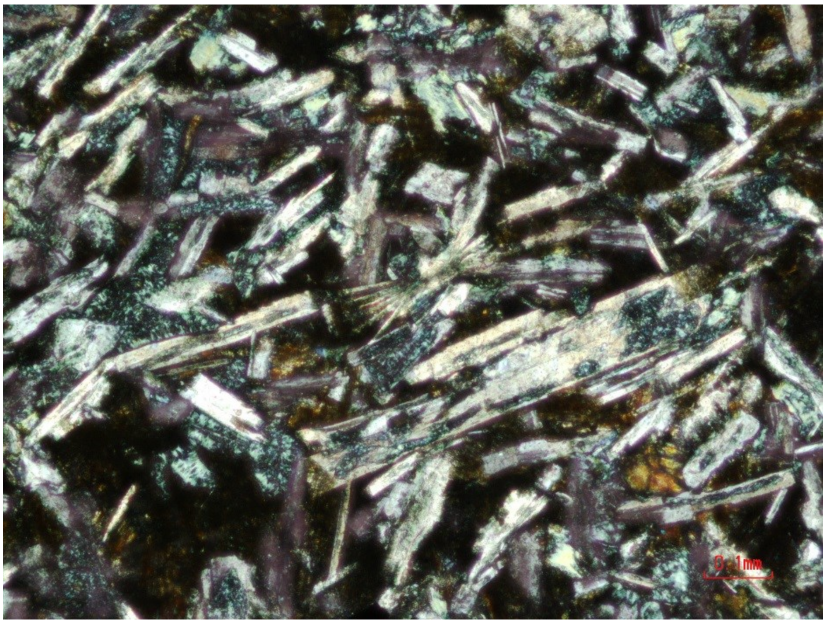


Figure 6. Photomicrograph in cross-polarised light of the basalt, composed of abundant plagioclase, and dark, murky replaced clinopyroxene and chlorite-replaced grains. Note bunch of fibrous plagioclase (centre) and larger plagioclase laths with hollow core texture infilled with chlorite (e.g. left of fibrous bunch). Thin section from 242.1 m depth. X 10 lens, base of photo is 1.2 mm. (Sample 2332882).

Figure. 7. Core photograph showing abrupt juxtaposition of amygdaloidal and more dense basalt in the upper part of a flow unit at 164 m depth.

Figure 8. Core photograph of boundary between green, finely amygdaloidal basalt on left and more red/brown basalt with abundant and larger amygdales at 196.85 m depth; possible pillow margin.

The basalt at the top of the mafic volcanic sequence (unit 1; 102.2-133.1 m) contains a strongly hematite-altered monomictic basalt breccia that is sporadically developed over approximately 10 m below the 1 m thick strongly amygdaloidal top of the basalt. The breccia is composed of mainly small (many <1 to 2 cm but range up to 20 cm), irregular-shaped to blocky angular clasts of aphyric basalt that occur in a matrix of more hematite-altered and finely fragmented material of probably the same composition (Fig. 9). Brecciated intervals within this interval are separated by mainly short lengths (<1.5 m) of either coherent basalt or fractured, crumbly basalt. The overall preservation of the breccia is poor due to the overprinting alteration and in situ fracturing, however, this breccia lacks the patchy amygdaloidal texture and is considered to have formed in response to increased viscosity (i.e. autobreccia).

The bulk of the flow unit interiors consist of darker grey, dense basalt that in places has a visible fine doleritic texture (Fig. 10) and which is either non- or weakly amygdaloidal. Amygdales in the interior of the flows are mostly small and typically slightly more round in shape. Some flows, however, (see Appendix I) contain narrow zones within the interior of the flow (e.g. unit 6: 231.1-

259.55 m) or in the lower half of the flow (e.g. unit 1b). In the weakly amygdaloidal interior of one of the basalt units unit 3), a weak planar flow fabric was observed (Fig. 11).

The basalt flow unit bases are marked by either narrow (10-20 cm) zones of monomictic breccia (upper two flows in Appendix I) or by abrupt increase in amygdales in the basal tens of cm to 1-2 m. The best-preserved of the breccia zones are composed of angular basalt clasts to 10 mm in size, which have a jig-saw fit arrangement and are interpreted as probably hyaloclastite. A 5 cm-wide chilled zone was observed of the lowermost flow (unit 6) that sits on the sandstone package at the end of the hole.

Figure 9. Core photograph of hematite-altered breccia; possible autobrecciated upper part of basalt flow unit at 104.95 m depth.

Figure 10. Core photograph of highly irregular and amygdaloidal clast within relatively dense basalt with scattered round chlorite amygdales at 138.2 m depth. The sample from the interior of a flow unit has a visibly coarser grained groundmass.

Figure 11. Core photograph of faint continuous flow foliation in the massive interior of basalt flow unit 3 at 166.9 m depth.

A 16 m-thick interval of hematite- and chlorite- altered red/brown and green monomictic basalt breccia and coherent basalt was logged from 215.1 m to 231.1 m. In detail, this interval is a sparsely plagioclase-phyric basalt that has been variably quench fragmented, leaving little affected basalt remnants up to 1 m in length, which are separated by coarse and fine monomictic breccia. The margins of coherent sections display well-preserved in situ breccia (Figs 12 and 13) characterised by blocky and splintery clasts that have a jig-saw fit texture. Coherent remnants and in situ brecciated basalt are interspersed with zones that range from a few cm to >1 m thick of fine monomictic breccia (Fig. 14). These intervals of finer breccia are composed of angular to splintery dark basalt clasts in a paler coloured and more altered matrix of very finely milled material. In thin section (sample 2332881), the smaller clasts have been completely replaced by chlorite (Fig. 15), however, retain the same relict textures as the adjacent less fragmented basalt. Narrow darker rims around the clasts are interpreted as the quenched rinds of the fragments. In between the basalt fragments, a secondary alteration assemblage of finely microcrystalline to fibrous chlorite, cryptocrystalline quartz rosettes, minor albite and a small amount of carbonate has obliterated the fragmented texture.

Figure 12. Core photograph of closely packed blocky clasts of finely amygdaloidal basalt in hyaloclastite from 218.2 m depth.

Figure 13. Core photograph of smoothly curved margin and rind of possible pillow and adjacent monomictic breccia (hyaloclastite) from 226.6 m depth.

Figure 14. Core photograph of fine monomictic basalt breccia (hyaloclastite) adjacent to more coherent basalt with smooth margins from 223.3 m depth.

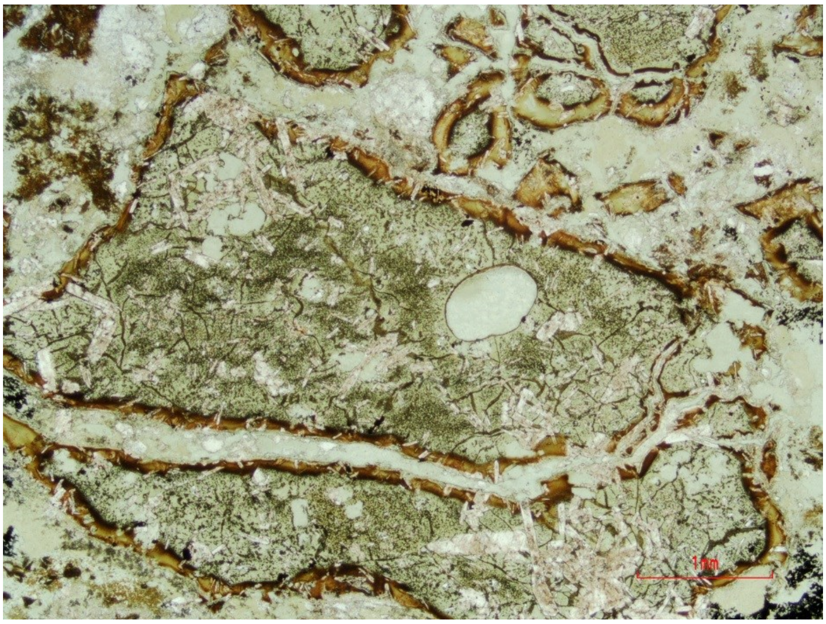


Figure 15. Photomicrograph in plane-polarised light of the chlorite-replaced and finely cracked fragments of the basalt, within which small amygdales and the groundmass bladed plagioclase is still visible despite quench fragmentation and alteration. Note the smooth to cuspate clast margins and narrow quenched rind and rind fragments in upper right of photo. The pale material between the fragments is finely microcrystalline chlorite and some quartz/albite. From 222.65 m depth. X 2 lens, base of photo is 6 mm. (Sample 2332881).

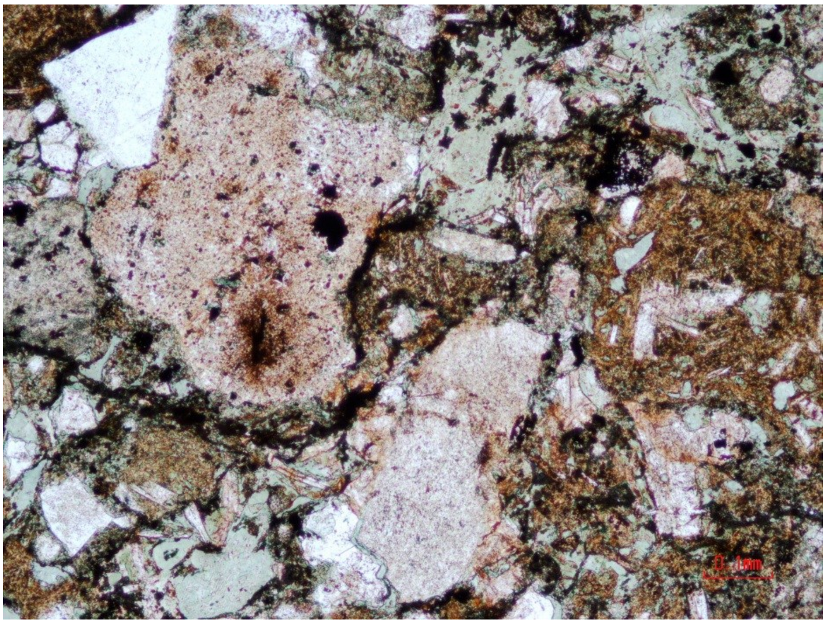


Figure 16. Photomicrograph in plane-polarised light highlighting some of the felsic volcanic component of the sandstone; quartz in upper left, pale pink micropoikilitic groundmass grain left of centre and pale alkali feldspar grain below centre. Most of the other grains in this view are of basaltic provenance including a fine brown basalt grain on right side and chlorite-replaced grains. From 260.92 m depth. X 10 lens, base of photo is 1.2 mm. (Sample 2332883).

In Figure 13, the smoothly curved ‘clast’ of basalt in the lower left of the photo may be a pillow margin. Elsewhere in this unit, other smooth boundaries such as this have radial cracks (e.g. 221.05 m). These features suggest that this monomictic basalt breccia unit may be a combination of pillow fragment breccia and hyaloclastite. At the base of the unit, a 1 cm and a 10 cm-wide band of fine sediment occurs within fine hyaloclastite and at the margin of hyaloclastite and coherent amygdaloidal basalt, respectively, and may represent inter-pillow sediment.

Drillhole MSDP03 ends in the top of a package of downward-coarsening volcaniclastic sedimentary rocks. Diffusely laminated green/brown siltstone at the top passes down into massive fine- to medium-grained sandstone with the basal 1 m consisting of massive brown, coarse-grained to finely pebbly sandstone. A thin section of medium-grained sandstone from the upper part of this interval contains mainly moderately sorted, sub-angular to sub-rounded grains of very fine basalt and chlorite-replaced grains/clasts but also includes up to 20 modal % of grains derived from quartz- and alkali feldspar-bearing felsic volcanic rocks (Fig. 16).

The mafic volcanic unit in MSDP03 preserves several features that suggest its emplacement in an at least partially subaqueous setting, although the eruption source may have been subaerial. These features include remnants of small, probable pillow margins, some associated with a thick unit that includes abundant hyaloclastite, in addition to smaller occurrences of hyaloclastite at the base of some flows and the presence of a normally graded moderately sorted sandstone and siltstone sequence at the drilled base. The mixed provenance of this sandstone sequence at the base of the hole, implies exposure of a felsic source at the time of basalt eruption. Mixing and reworking of the two sediment compositions is likely to have occurred in a relatively high energy environment, however, the normally graded sandstone sequence suggests deposition in a lower energy body of water.

REFERENCES

Fabris, A.J., Tylkowski, L., Brennan, J., Flint, R.B., Ogilvie, A., McAvaney, S.O., Werner, M., Pawley, M., Burtt, A.C., Rowe, R. Henschke, C., Chalmers, N.C., Rechner, S.I., Hardwick, X. 2017. *Mineral Systems Drilling Program in the southern Gawler Ranges, South Australia*, Report Book 2016/00030. Department of State Development, South Australia.

Krapf, C.B.E., Werner M., Pawley, M.J. and McAvaney, S.O. 2016. *Six Mile Hill Map Sheet – Mineral Systems Drilling Program Special Map Series*, 1:75 000 scale (digital edition). Department of State Development, South Australia. https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/DIGIMAP00088.pdf

McAvaney, S.O., Werner, M., Pawley, M.J., Krapf, C.B.E. and Nicolson, B.E. 2016. *Geology of the Six Mile Hill 1:75 000 Map Sheet, Mineral Systems Drilling Program Special Map Series*, Report Book 2016/00014. Department of State Development, South Australia. https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/RB201600014.pdf

Pawley, M.J., Werner, M., Krapf, C.B.E. and McAvaney, S.O. 2016b. *Interpreted Proterozoic solid geology of Six Mile Hill - Mineral Systems Drilling Program Special Map Series, Map Sheet (digital edition)*. Department of State Development, South Australia. https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/DIGIMAP00089.pdf

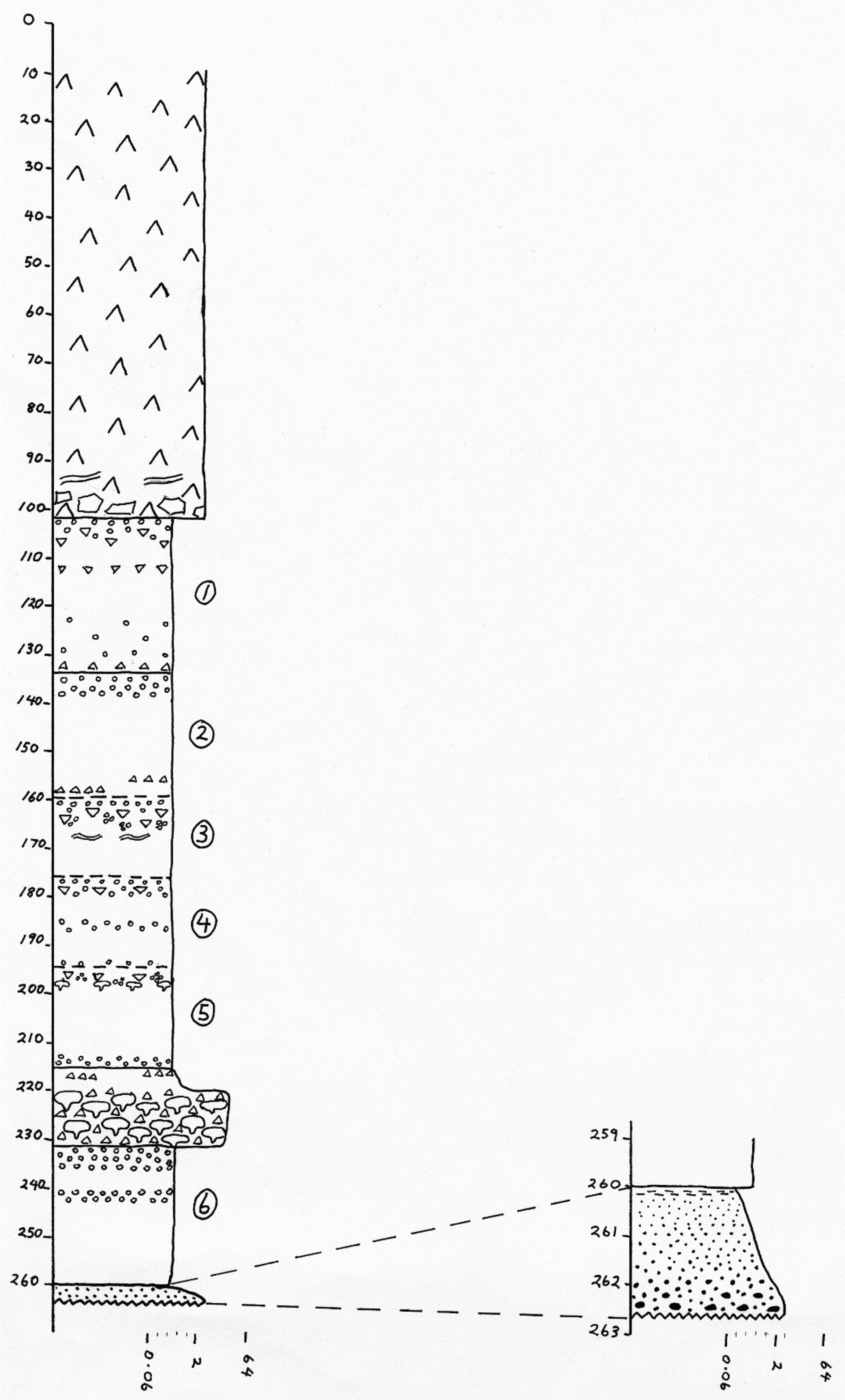
Simpson, C. 2017a. *Report on Mineral Systems Drilling Program drillhole MSDP01, Six Mile Hill area*, Report book 2017/00023. Department of the Premier and Cabinet, South Australia. https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/RB201700023.pdf

Simpson, C. 2017b. *Report on Mineral Systems Drilling Program drillhole MSDP04, Six Mile Hill area*, Report book 2017/00025. Department of the Premier and Cabinet, South Australia. https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/RB201700025.pdf

Simpson, C. 2017c. *Interpretative report on the lower Gawler Range Volcanics in the Six Mile Hill area*, Report book 2017/00026. Department of the Premier and Cabinet, South Australia. https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/RB201700026.pdf

APPENDIXES

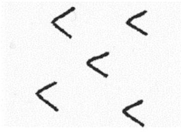
APPENDIX I. GRAPHIC LOG OF DRILLHOLE MSDP03



Drillhole log legend

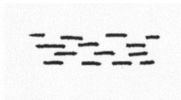
Symbols for felsic units

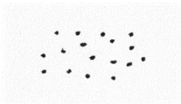
Predominantly feldspar-phyric 

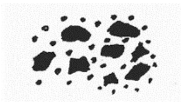
Quartz- and feldspar-phyric 

Monomictic felsic breccia 

Symbols for volcaniclastic rocks

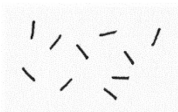
Mudstone/siltstone 

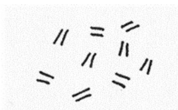
Sandstone 

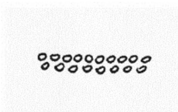
Pebbly sandstone/volcaniclastic breccia 

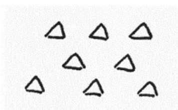
Symbols for basaltic units

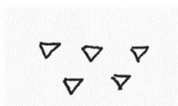
Aphyric to sparsely plagioclase-phyric basalt **Blank**

Moderately (~5-10%) plagioclase-phyric basalt 

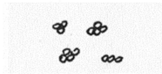
Relatively plagioclase-rich basalt 

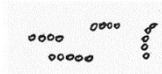
Conspicuously amygdaloidal basalt 

Monomictic basalt breccia; probable hyaloclastite 

Monomictic, poorly-defined breccia; flow-top 

Textural symbols and other features: applicable to both felsic and basaltic rocks

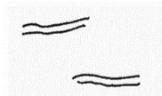
Patchy amygdaloidal texture 

Banded amygdaloidal texture 

Possible small pillow margins 

Sediment rafts; peperite 

Plagioclase megacrysts 

Flow-banding and flow foliation in groundmass 

Lithophysae and/or vughs 

APPENDIX II. STRATIGRAPHIC LOG NOTES FOR DRILLHOLE MSDP03

0-10.3 m: Quaternary cover including regolith/saprolite

10.3-102.2 m: Felsic volcanic unit

Massive and porphyritic texture evident at 10.3 m, clearer by 14 m.

Pale pink near top, darkening to mid-brick colour below ~23 m.

Pink albitised plagioclase phenocrysts to 2-3 mm, ~15-20 modal %.

Brittle fractures throughout unit but more pronounced zones of broken rubbly core around 25 m, 29-36 m, 45.2-49 m.

Rare isolated quartz phenocrysts to 4 mm below 40 m.

Core photo at 50.4 m (below) of general porphyritic texture.

Thin section at 50.8 m = sample 2332877

Broken core zones; ~57.9-59.2 m, 61.2-62.3 m, 66-68 m.

Core photo at 78 m (below); plagioclase phenocrysts more obvious (~20 modal %) and slightly larger than higher in unit, small dark ferromagnesian grains, very rare quartz phenocrysts.

Thin section at 81.33 m = sample 2137673

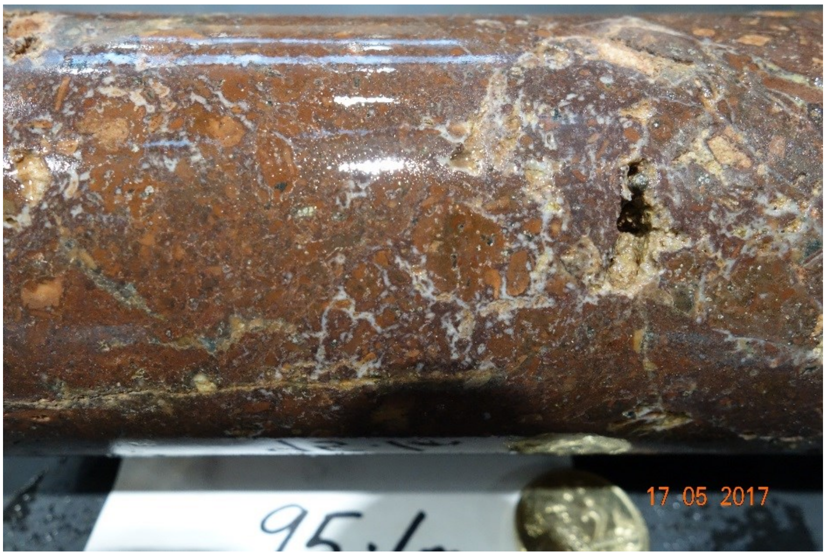
Core photo at 85.7 m (below); includes rare larger phenocrysts to 10 mm but most are <5 mm.

Thin section at 91.05 m = sample 2137674

Weak flow foliation defined by some aligned plagioclase and diffuse, fine groundmass banding evident below ~91 m.

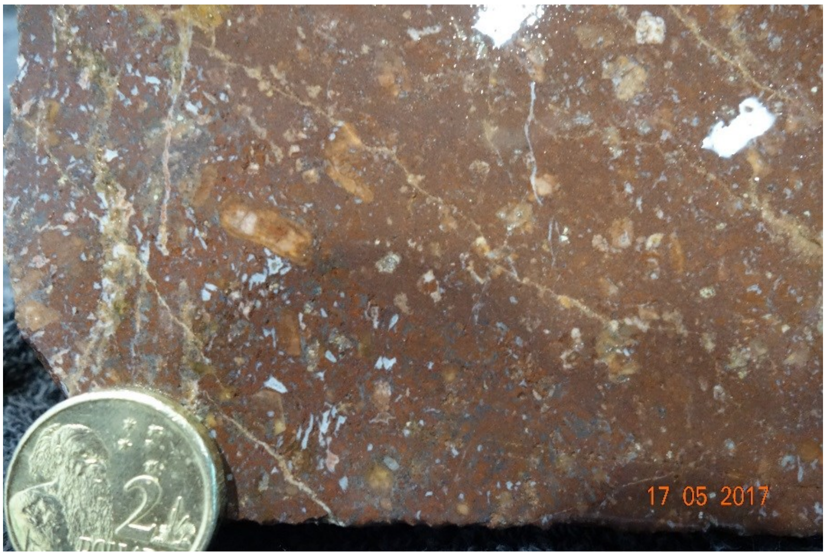
Core photo at 93 m (below); weak banding/ flow foliation.

Brecciation (possible fine autobreccia) and more altered sporadically from 95 m – see core photo at 95.1 m (below).



Small irregular quartz-filled amygdales visible, slightly vuggy.

Core photo at 101.1 m (below); porphyritic texture and quartz amygdales.



Phenocrysts appear sparse and small and rock finely brecciated over basal 20-30 cm.

Lower contact fractured but likely to be sharp.

102.2-262.6 m: Mafic volcanic unit

102.2-133.1 m: *Aphyric basalt with brecciated top and base*

102.2-103.2 m: massive, very sparsely plagioclase-phyric red/brown amygdaloidal basalt with abundant amygdales to >1 cm.

103.2-~113.7 m: red/brown monomictic breccia with irregular to blocky A clasts to 8 cm in the upper few m, strongly hematite-altered, some jig-saw fit texture; possible autobreccia. From 107-108.5 m, more coherent basalt with low vesicularity but below this broken core with more breccia texture with jig-saw fit below 110 m and clasts to >20 cm.

Core photos at 104.95 m (below), 106.2 m and 111.9 m of monomictic breccia.

~113.7-132.9 m: red/brown mainly aphyric, very weakly amygdaloidal basalt to 120 m, below this a moderate content of small (<1-2 mm) chlorite amygdales to base and rare plagioclase phenocrysts to 5 mm between 120 & 121 m. Fractured and possibly brecciated below 131.5 m.

132.9-133.1 m: 20 cm of dark green/grey fine breccia, sharp base.

Core photo at 133 m (below); fine monomictic breccia and silica/chlorite alteration.

133.1-159.15 m: *Aphyric basalt with small brecciated base*

Moderately very finely amygdaloidal and red/brown in upper 5 m; pink amygdales (albite?) near top, small chlorite amygdales more obvious below 135 m, locally up to 25-30 modal %.

Colour change to green/grey below 137 m and fewer amygdales below 138 m; massive, dense mid-grey basalt.

<u>Core photo at 138.2 m (below)</u>: dark, strongly amygdaloidal possible scoria clast.

Very finely doleritic texture below ~145-147.5 m.

<u>Core photo at 155.3 m (below)</u>; dark chlorite-lined fracture in aphyric basalt.

Monomictic breccia at 156.8 m (10 cm) and 159.05 m (10 cm); the latter with 5-10 mm angular clasts and jig-saw fit – probable hyaloclastite, taken as base.

159.15-176.0 m: *Aphyric basalt with variably patchy amygdaloidal texture*

Dark grey, "glassy-looking" at top, becomes moderately amygdaloidal (to 5 mm size) and below 161 m looks slightly brecciated and larger amygdales below 161.5 m.

By 162.4 m, colour change to patchy red/brown and green and development of patchy amygdaloidal texture in which red/brown dense basalt is juxtaposed against green highly and finely amygdaloidal (35%) basalt patches to 10 cm diameter; possibly scoriaceous flow-top breccia?

Core photo at 164 m (below) of margin between relatively dense basalt and highly amygdaloidal basalt,

and core photo at 166.9 m (below) of faint flow foliation.

Amygdales decline to sparse below 165 m and colour changes to greenish/grey; massive fine basalt.

Small (10-20 cm) zones of fine breccia e.g. 169.5 m, 169.85 m, 171.8 m and 173 m but these look more secondary than primary.

176.0-~194 m: *Aphyric to very sparsely plagioclase-phyric basalt with patchy amygdaloidal texture near top*

Aphyric and moderately but very finely chlorite amygdaloidal and pale greenish/grey with minor red/brown patches near the top. Displays same patchy texture re amygdale content as unit above to ~179 m; possible scoriaceous flow top?

Very rare plagioclase phenocrysts below 179 m, fewer amygdales and mainly mid grey colour. Narrow zones of later quartz-, carbonate- or chlorite-lined fractures give parts of the basalt a brecciated texture.

Small (1-2 mm) chlorite amygdales more obvious 185-187.1 m, then overall relatively sparse to 193.5 m.

Base of flow unclear but slightly more amygdaloidal 194-194.2 m.

~194-215.1 m: *Aphyric to very sparsely plagioclase-phyric basalt with patchy amygdaloidal texture near top*

Inferred upper part of flow unit marked by patchy amygdale development as in units above (amygdale content varies from low to ~30 modal %) and pronounced colour change to brick red and green to 197 m, both features shown in core photo at 196.85 m (below), which may be a pillow margin?

Between ~197 m to 213.5 m, much of the core is broken but appears to be more massive and homogeneous grey basalt with a fine doleritic texture and overall low vesicularity.

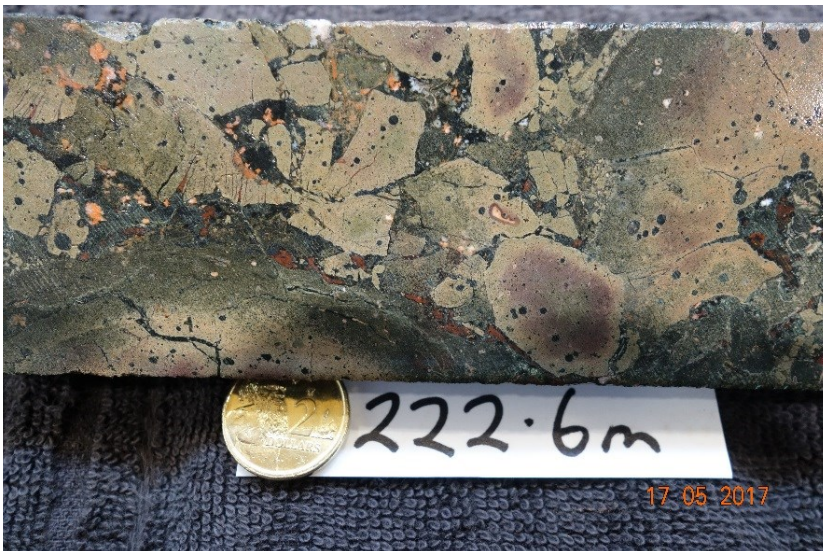
Chlorite amygdales increase in abundance to 15-20 modal % and size (to >5 mm) below 213.5 m to 215.1 m and colour changes from grey to blotchy green and red/brown.

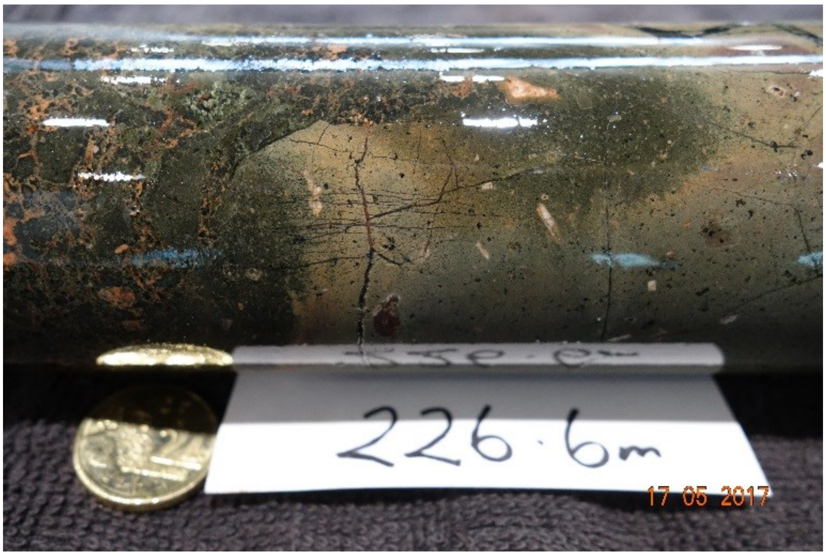
215.1m-231.1 m: *Monomictic basalt breccia and sparsely plagioclase-phyric basalt (possibly pillow remnants)*

Mostly coherent, finely amygdaloidal basalt near top (215.1-215-9.8 m) with small amounts of monomictic autoclastic breccia, probably hyaloclastite. Curved and banded margins may be pillows.

Distinctive patchy brick red/brown and green colour throughout.
Small intervals of breccia occur at 215.1-215.4 m and 218-218.4 m have closely packed blocky clasts – see core photos at 218.2 m and 218.3 m (below)

The main breccia interval extends 219.8-23-231.1 m and consists mainly of closely packed brecciated basalt (e.g. core photo at 222.6 m, below) to more finely (<10 mm) fragmented material (e.g. core photo at 223.3 m, below), both interpreted as in situ hyaloclastite. Contacts with mainly short (5 cm-<1 m) sections of less fragmented aphyric basalt are typically smoothly curved to lobate, suggestive of pillow margins (e.g. core photo at 226.6 m, below) with interstitial hyaloclastite.





<u>Thin section at 222.65 m = sample 2332881</u>

1 cm of fine-grained sandstone at 230.85 m and 10 cm of thinly bedded sandstone/siltstone at 230.95 m may be inter-pillow sediment at lower contact of breccia interval.

231.1-259.55 m: *Sparsely plagioclase-phyric basalt with amygdaloidal upper part*

231.1- 237 m: sparsely plagioclase-phyric, amygdaloidal basalt that contains relatively abundant (up to 20 modal %) chlorite amygdales mostly <7 mm diameter.

Mainly red/brown, hematite-altered in upper 4-5 m.

237- ~240.1 m: massive green/grey basalt with fine doleritic texture, includes a few cm-wide breccia at 239.3 m.

240.1-244.5 m: more amygdaloidal part of same basalt, fewer amygdales below 244.5 m.

<u>Thin section at 242.1 m = sample 2332882</u>

244.5-259.55 m: dark grey, massive, weakly amygdaloidal, sparsely porphyritic basalt with visible doleritic groundmass ~255-~259 m, fining to a 5 cm very fine-grained chilled planar base.

259.55-262.6 m: *Graded volcaniclastic sandstone*

Diffusely planar laminated green/brown siltstone/very fine sandstone in upper 30-40 cm.

Passes down into diffusely planar laminated fine- to medium-grained brown sandstone with medium-grained below 261 m and pebbly sandstone below 261.6 m.

<u>Thin section at 260.92 m = sample 2332883</u>

APPENDIX III. PETROGRAPHIC DESCRIPTION OF SAMPLES FROM DRILLHOLE MSDP03

Felsic volcanic unit

SAMPLE 2332877:50.8-50.88 m

This sample is an evenly porphyritic rock of probable dacitic composition, containing an estimated total 25-30 modal % phenocrysts, which range in size from 0.5 to 6 mm. The estimated mode for the sample (excluding replacement minerals) is 20-23% feldspar phenocrysts, mostly plagioclase, 3-4% chlorite-replaced ferromagnesian phenocrysts, 1% opaques and accessory quartz and apatite with the remaining ~70% consisting of quartz-feldspathic groundmass. The main secondary replacement minerals are sericite, chlorite, hematite and minor carbonate.

The majority of the phenocryst component is feldspar (~20-23 modal %), which has undergone varying degrees of alteration by sericite and very fine hematite (Fig. A1). Many feldspars retain faint traces of multiple twinning and/or compositional zoning indicating the feldspar is mainly plagioclase (up to 20 % of the rock), however, some strongly hematite-dusted crystals are simply twinned and retain a faint microperthitic texture, suggesting that up to 3 % are alkali feldspar. The better twinned plagioclase grains have extinction angles of ~15°, indicating their composition is albite. Regardless of size, the feldspar phenocrysts are subhedral to euhedral and a few are embayed. Ferromagnesian phenocrysts have been completely replaced by chlorite, carbonate and an opaque mineral and occur as subhedral laths to 2 mm in length or as smaller more equant crystals, either singularly or in small aggregates, some with altered plagioclase and small opaques (probably magnetite). The original mineral is most likely to have been an amphibole and/or pyroxene. The sample contains a 3 mm-long embayed quartz phenocryst and a much smaller micro-phenocryst. Accessory apatite crystals are conspicuous, occurring as euhedral, bladed microphenocrysts to 0.7 mm in length.

The groundmass is composed of coarsely intergrown hematite-altered feldspar and quartz with a granophyric texture in which mainly 0.1-0.2 mm-long feldspar grains are enclosed within more irregular to bladed quartz. At low magnification, a blotchy texture within the groundmass is evident (Figs A1 and A2). Individual blotches with even extinction are up to 1 mm in diameter and are interpreted as a micropoikilitic texture, resulting from slow devitrification of an originally glassy groundmass.

The glassy nature of the groundmass indicates that it is either a coherent rock (lava or high-level sill) or a densely welded ignimbrite. The absence of fragmental features in either the phenocrysts or groundmass or other features such as included lithic clasts, suggest this sample is unlikely to be of pyroclastic origin and it is interpreted as coherent.

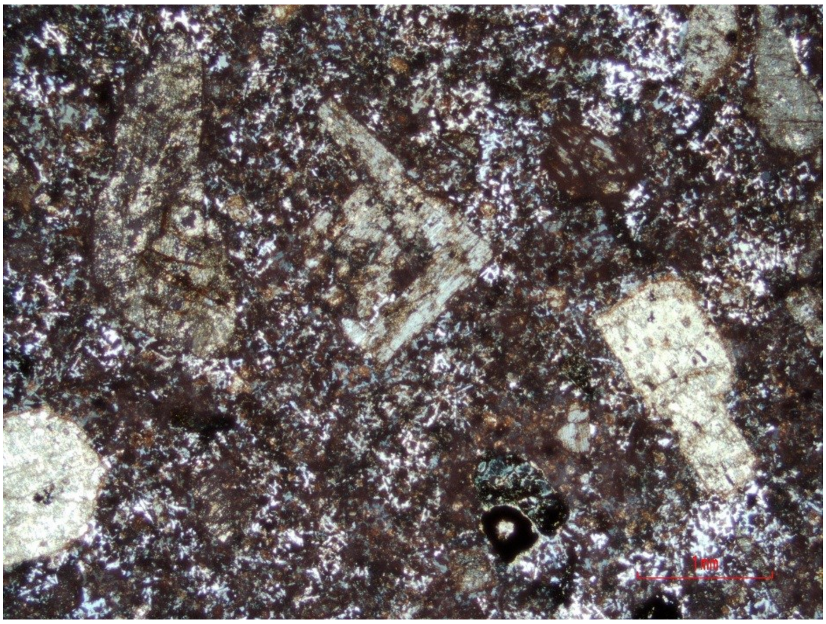


Figure A1: Sample 2332877. Photomicrograph in cross-polarised light of the overall porphyritic texture of the interior of the felsic volcanic unit in MSDP03. The phenocrysts are altered plagioclase and a small chlorite-replaced ferromagnesian mineral at centre base of photo (next to opaque). The blotchy texture in the granophyric quartz-feldspar groundmass is micropoikilitic texture. X2 lens, base of photo is 6 mm.

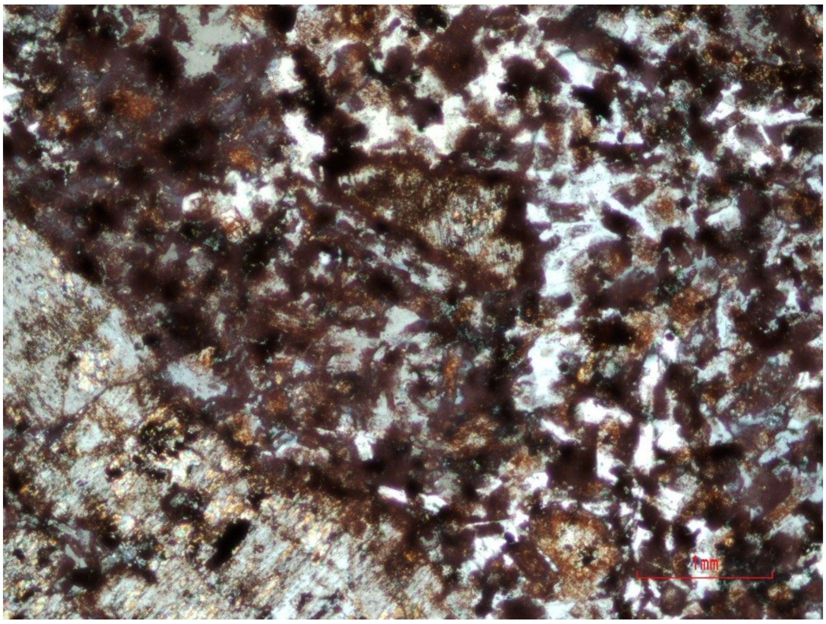


Figure A2: Sample 2332877. Photomicrograph in cross-polarised light showing the granophyric intergrowth of hematite-altered feldspar and quartz in the groundmass, adjacent to a plagioclase phenocryst in lower left corner. X10 lens, base of photo is 1.2 mm.

SAMPLE 2137673: 81.33-81.38 m

This sample is a porphyritic rock of probable dacitic composition that is very similar to sample 2332877, from a higher level in this unit and is therefore described only briefly here. It contains ~25-30% phenocrysts, which range in size from 0.4 to 5.5 mm (Fig. A3). The estimated mode for this rock is up to 23% feldspar phenocrysts, mostly plagioclase, 2-3% chlorite-replaced ferromagnesian phenocrysts, 1% opaques and accessory quartz and apatite with the remaining ~70-75% consisting of quartz-feldspathic groundmass. A single 0.075 mm-long, slightly abraded zircon was observed. The main secondary replacement minerals are sericite, murky fine chlorite/smectite, hematite and carbonate. The ferromagnesian minerals are more intensively altered and original grain shape has largely been lost and feldspar is also slightly more affected in this sample compared with the thin section from 50.8 m. This stronger alteration and slightly murkier groundmass, mean that phenocrysts in sample 2137673 do not stand out as well.

Many of the feldspar grains retain at least faint multiple twinning and alkali feldspar has not been confidently identified. Quartz occurs as a couple of rounded microphenocrysts, the largest being 0.6 mm. The accessory apatite in this sample occurs as prominent laths, one to 1.5 mm in length. The groundmass has the same micropoikilitic texture and consists of a coarsely intergrown (granophyric) aggregate of hematite-altered feldspar and more interstitial quartz, as in sample 2137673.

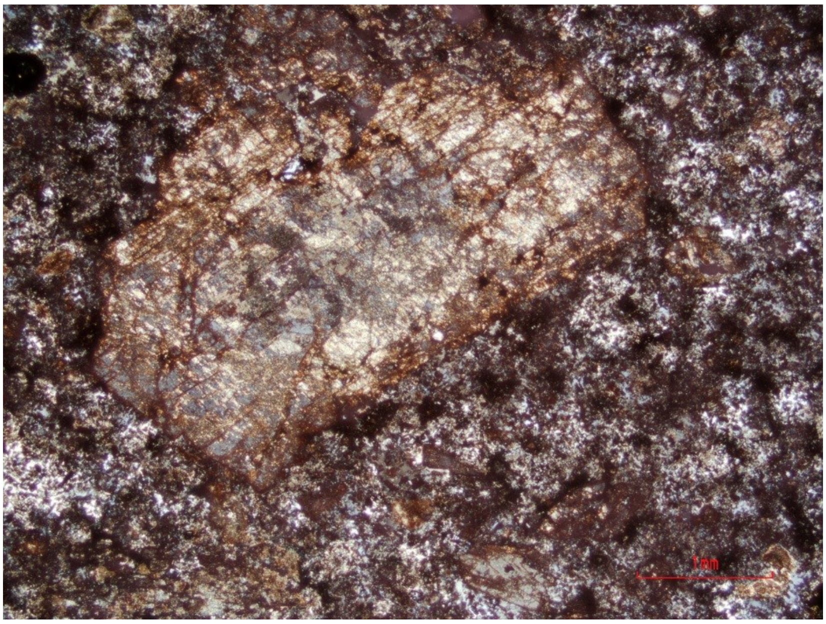


Figure A3: Sample 2137673. Photomicrograph in cross-polarised light of the felsic volcanic unit from MSDP03, 81.33 m, centred on a large sericite-carbonate-hematite-altered plagioclase phenocryst set in micropoikilitic groundmass that also contains scattered smaller plagioclase phenocrysts (e.g. left of scale bar). X2 lens, base of photo is 6 mm.

SAMPLE 2137674: 91.05-91.1 m

This sample is a porphyritic rock of probable dacitic composition that is very similar to samples 2332877 and 2137673 and is therefore described only briefly here. It contains ~25-30% phenocrysts, which range in size from 0.4 to 5 mm, although the sample includes a single altered plagioclase lath that is 10 mm in length. The estimated mode for this rock is 22-24% feldspar phenocrysts, mostly plagioclase, 3-4% chlorite-replaced ferromagnesian phenocrysts, 1% opaques and accessory quartz (a single 0.3 mm microphenocryst) and apatite with the remaining ~70-75% consisting of quartz-feldspathic groundmass. The main secondary replacement minerals are sericite and fine hematite after feldspar and in the groundmass and a mixture of chlorite and muscovite, murky carbonate and opaques after ferromagnesian minerals.

In this sample, the majority of the feldspar phenocrysts appear to be plagioclase, however, there are a few hematite-altered, simply-twinned phenocrysts to 2 mm in size, which have a relict microperthitic texture (probable alkali feldspar). Most of the feldspar phenocrysts are subhedral and tabular in form and some have undergone a small amount of embayment. The ferromagnesian phenocrysts occur as single small (<1 mm) phenocrysts and in aggregates with feldspar. A few with better crystal form have shapes that are more consistent with pyroxene than amphibole. Apatite microphenocrysts in this sample are very elongate, euhedral crystals up to 1.2 mm in length. The groundmass in this sample is noticeably finer grained than in sample 2332877, which is from the interior of the unit but still has the same micropoikilitic texture, consisting of a granophyric intergrowth of feldspar and quartz. A very weak linear fabric is defined by discontinuous 1-2 mm-wide folia of dark, murky chlorite, clay and iron oxides, which may be picking out original flow-banding defined by bands of slightly different devitrification grainsize and/or texture.

Mafic volcanic unit

SAMPLE 2332881: 222.65-222.75 m

This sample comes from a thick interval of monomictic basalt breccia, which was interpreted in drill core as an in-situ hyaloclastite. This interpretation is supported by the thin section features; the mid orange/brown fragmented basalt has highly indented and irregular boundaries with a green matrix composed of smaller fragments of the same basalt, which has been entirely chlorite-replaced. Between these smaller fragments, is an alteration assemblage of microcrystalline chlorite and smaller amounts of secondary quartz and albite, which has largely obliterated the original texture in these zones. The least affected parts of the basalt are sparsely plagioclase-phyric, containing a few (2-3 modal %) albitised plagioclase phenocrysts to 3.5 mm in length. The basalt groundmass is composed of abundant hematite-stained, ex-ferromagnesian minerals (most likely small clinopyroxene grains) with a grainsize of 0.1-0.2 mm, which sub-ophitically enclose bladed albitised plagioclase microphenocrysts, which range from <0.1 to 0.4 mm in length. Some of the bladed plagioclase laths have swallow-tail terminations, indicative of rapid cooling (Fig. A4). Chlorite occurs as a replacement of rare, small phenocrysts (look like olivine shapes) and as the main infill mineral of the relatively abundant small, round amygdales in the basalt. The chlorite-filled amygdales range in size up to 1.5-2 mm diameter and there are also a few other amygdales, which have been in-filled with quartz with a cryptocrystalline rosette texture and rare albite or in some cases, by all three minerals.

The fragments of basalt which have been completely replaced by chlorite, range in size up to ~8 mm and have a well-developed fine fracture texture, with some poorly developed perlitic cracks, which reflects hydration of original glass (Figs A5 and A6). Clast shapes vary from blocky to cuspate and all have a 0.1 mm-wide rim of cryptocrystalline chlorite and/or clay/zeolite of a more brownish olive colour, which are interpreted to be the originally palagonitised rinds of the fragments. The replacement chlorite within the clasts varies from barely microcrystalline and massive to slightly coarser grained and fibrous in texture. Many of the larger basalt clasts contain the same chlorite amygdales as found in the host basalt and the bladed groundmass plagioclase crystals are still evident. The zones between the chlorite-replaced clasts and infills within the fractured orange/brown host basalt consist mainly of chlorite, both cryptocrystalline and fibrous aggregates but also includes rosettes of cryptocrystalline quartz, some also with albite and a small amount of carbonate. Small fragments of the ex-glassy rinds of clasts attest to preferential alteration of the most strongly quench-fragmented glassy material. These zones also contain the ghost outlines of original phenocrysts, presumed plagioclase from the basalt. These have been replaced by chlorite and in turn by black, very fine opaques, probably magnetite and some chlorite.

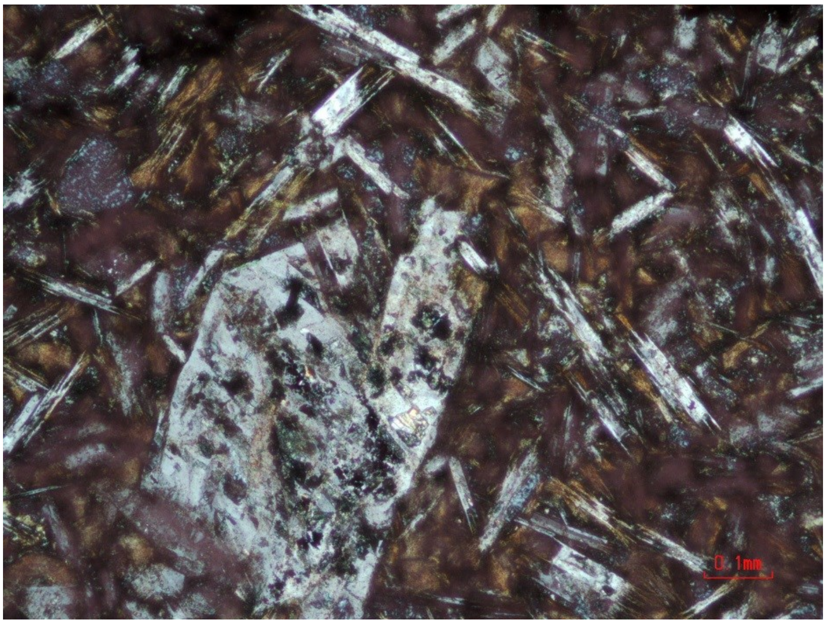


Figure A4: Sample 2332881. Photomicrograph in cross-polarised light of the host basalt, showing a small plagioclase phenocryst and the bladed plagioclase in the groundmass, which has feathery to swallow-tail ends, indicating rapidly cooling. The dark material enclosing the groundmass plagioclase is chlorite; the brownish variety replacing groundmass minerals (probably pyroxene), and the finely microcrystalline chlorite between the grains. X10 lens, base of photo is 1.2 mm.

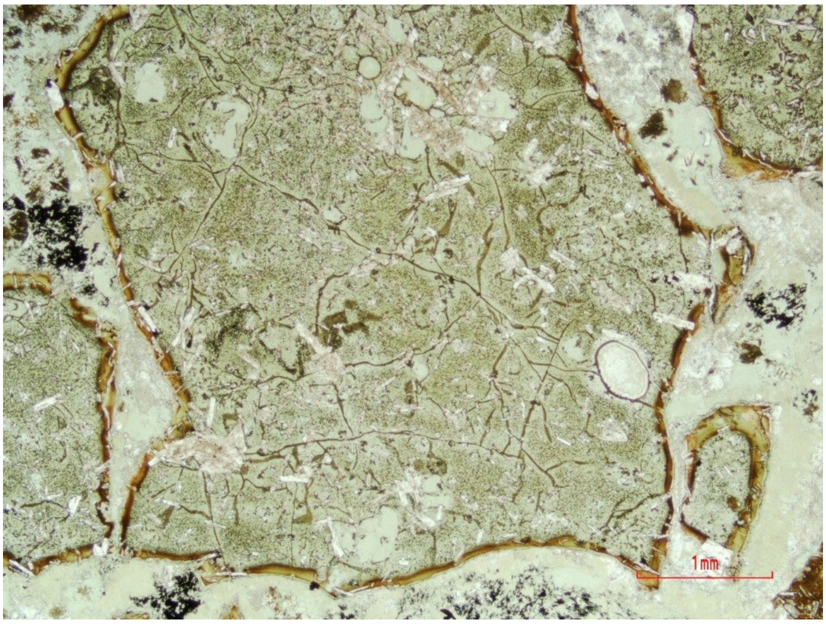


Figure A5: Sample 2332881. Photomicrograph in plane-polarised light of the chlorite-replaced and finely cracked fragments of the basalt, within which there are small amygdales and the groundmass bladed plagioclase is still visible despite quench fragmentation and alteration. Note the smooth to cuspate clast margins and narrow quenched rind. The pale material between the fragments is finely microcrystalline chlorite and some quartz/albite. X2 lens, base of photo is 6 mm.

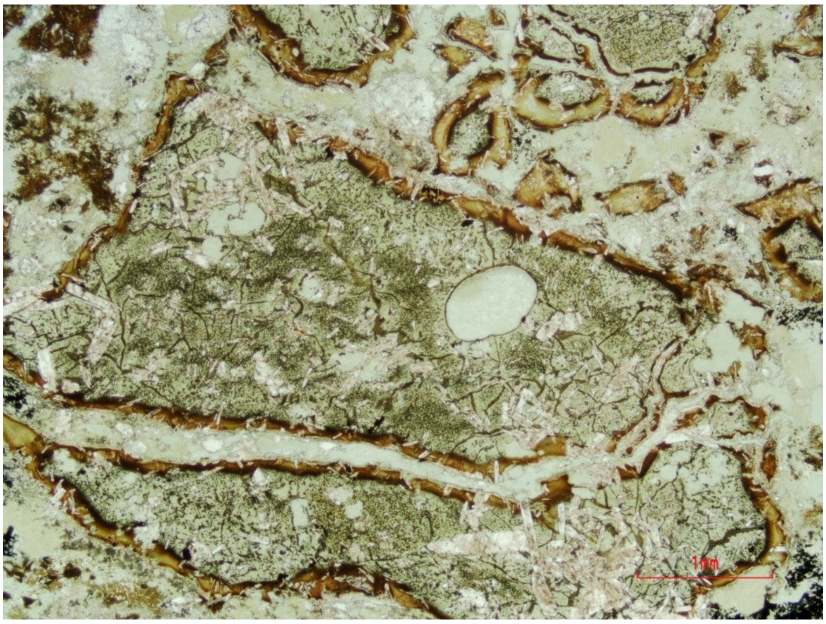


Figure A6: Sample 2332881. Photomicrograph in plane-polarised light of the chlorite-replaced and finely cracked fragments of the basalt, as for Figure A5. Note the jig-saw fit clast arrangement and fragments of quenched clast rinds in upper right of photo. The pale material between the fragments is finely microcrystalline chlorite and some quartz/albite. X2 lens, base of photo is 6 mm.

SAMPLE 2332882: 242.1-242.15 m

This sample is from an interval of very sparsely plagioclase-phyric amygdaloidal basalt. Plagioclase phenocrysts do not occur in the thin section and it consists entirely of a coarsely microcrystalline aggregate of murky 0.1-0.2 mm grains of altered clinopyroxene (rare residual pyroxene but most chlorite/clay-altered) and bladed plagioclase to 0.6 mm in length and interstitial secondary chlorite, which is indistinguishable from the basalt in sample 2332881. The plagioclase displays quenched textures in hollow cores and swallow-tail terminations and less commonly, bow-tie-like bunches of tiny fibrous plagioclase crystals (Fig. A7).

Approximately 20% of the thin section are amygdales in the aphyric basalt, which vary in shape from round to more common elongate and irregular and range up to 10 mm in length. The main infill mineral is chlorite, which occurs as variably cryptocrystalline to microcrystalline to fibrous and radiating aggregates, and pale pink granular albite (Fig. A8). Fine quartz, carbonate and black opaques are rare within the amygdales.

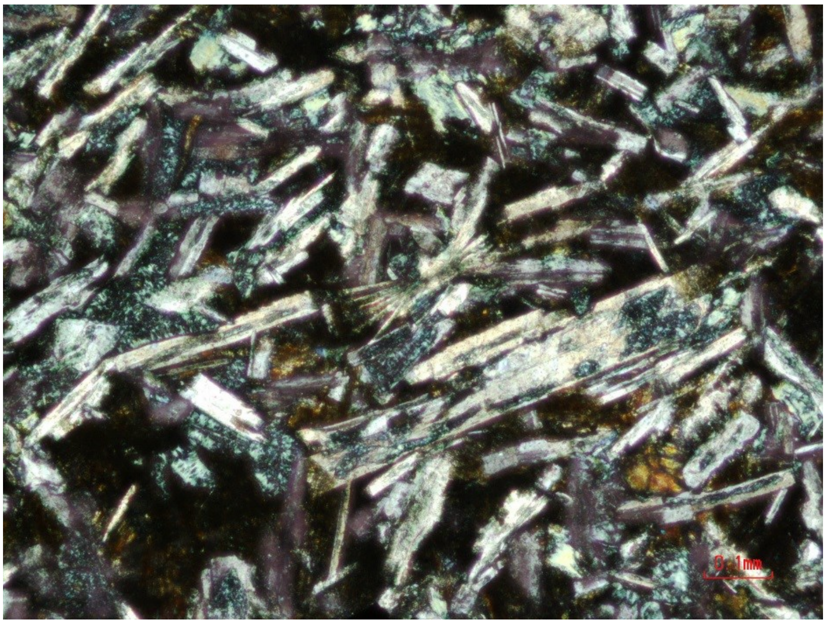


Figure A7: Sample 2332882. Photomicrograph in cross-polarised light of the basalt, composed of abundant plagioclase, and dark, murky replaced clinopyroxene and chlorite-replaced grains. Note tiny bunch of fibrous plagioclase (centre) and larger plagioclase laths with hollow core texture (infilled with chlorite e.g. left of fibrous bunch. X10 lens, base of photo is 1.2 mm.

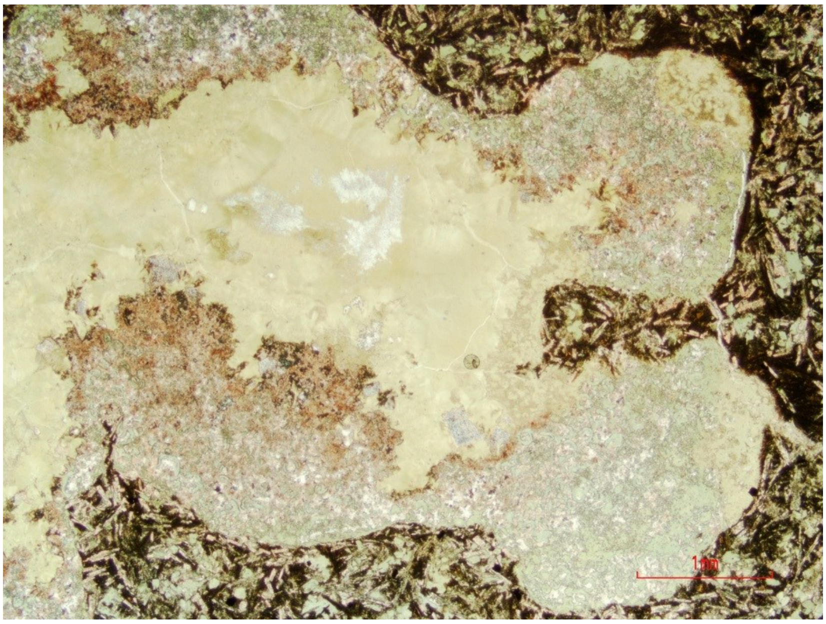


Figure A8: Sample 2332882. Photomicrograph in plane-polarised light of part of a large, elongate amygdale with smooth but irregular margins. The infill consists of pale green chlorite, mainly in centre but partly intergrown with the pale to pink granular albite around margins. The white in the centre is carbonate. X2 lens, base of photo is 6 mm.

SAMPLE 2332883: 260.92-261.0 m

This sample is a massive, medium-grained volcaniclastic sandstone of predominantly basaltic provenance. It does, however contain up to 10 modal % quartz, 5-7 modal % alkali feldspar and equant plagioclase, 5 modal % alkali feldspar-phyric lithic grains and a few grains of micropoikilitic felsic groundmass, indicating at least minor input from a felsic volcanic source (Figs A9 and A10). The remainder of the grains (~80 % of the mode) are more altered and are likely to be mainly of basaltic provenance. Many of these grains are a brick coloured, very finely plagioclase-phyric basalt, and there are also darker, red/brown aphyric basalt, abundant small chlorite-replaced grains and less abundant chlorite-replaced grains which contain tiny amygdales (Fig. A11). Some of the chlorite-altered grains are also partly or nearly completely replaced by opaques. The sample also contains 1-2 modal % probable siltstone lithic grains, some of which are finely laminated.

The grains range in size up to 1 cm but average grainsize is <0.5 mm. Grain shape of many of the mafic and felsic lithic grains is sub-angular to sub-rounded but many of the quartz and feldspar crystal fragments are more angular. The grains are closely packed and there appears to be little fine matrix. The sandstone is considered to be moderately sorted and texturally to be mature.

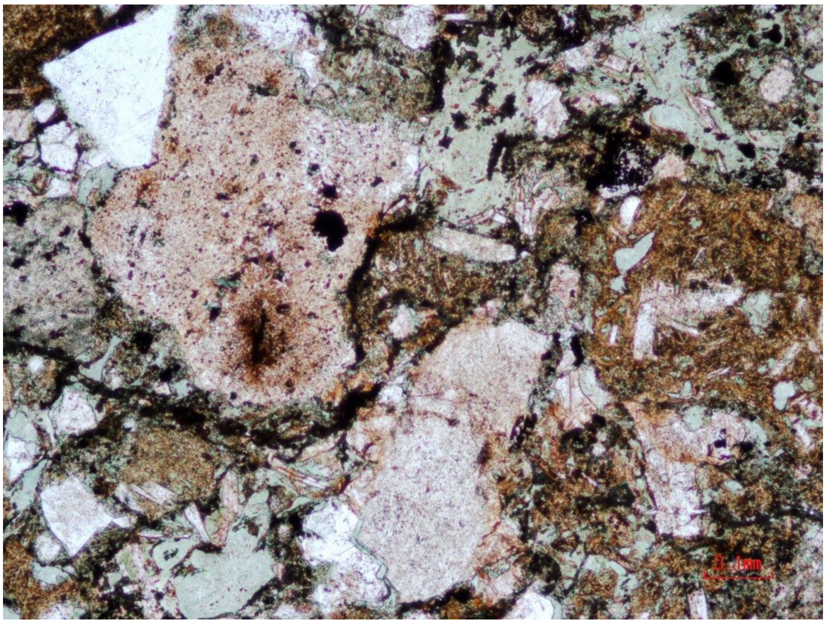


Figure A9: Sample 2332883. Photomicrograph in plane-polarised light highlighting some of the felsic volcanic component of the sandstone; quartz in upper left, pale pink micropoikilitic groundmass grain left of centre and pale alkali feldspar grain below centre. Most of the other grains in this view are of basaltic provenance including a fine brown basalt grain on right side and chlorite-replaced grains. X10 lens, base of photo is 1.2 mm.

Figure A10: Sample 2332883. Photomicrograph in cross-polarised light showing the same view as in Figure A9, in which the more felsic grains stand out from the murkier basaltic-derived grains. X10 lens, base of photo is 1.2 mm.

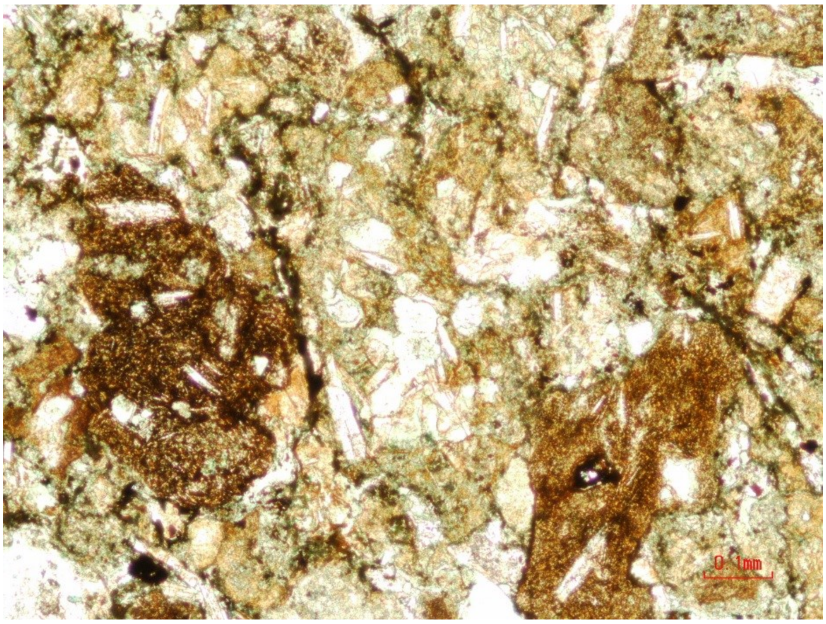


Figure A11: Sample 2332883. Photomicrograph in plane-polarised light centred on a poorly-defined chlorite amygdaloidal basalt grain with two better-defined, brown, finely plagioclase-phyric basalt grains. X10 lens, base of photo is 1.2 mm.