Regional geology and mineral systems of the Stavely region, western Victoria

Data release 4 – Drill core rock property measurements

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# Contents

Executive summary ................................................................................................................................. iv

1 Introduction ............................................................................................................................................ 1
   1.1 Project Background .................................................................................................................. 1
   1.2 Geography .............................................................................................................................. 2
   1.3 Mineral exploration in the Stavely region ............................................................................... 2
   1.4 The Stavely Project ............................................................................................................... 3

2 Geological overview .............................................................................................................................. 8

3 Overview of pre-competitive stratigraphic drilling in the Stavely Project area .................................... 11
   3.1 Drilling objectives ............................................................................................................... 11
   3.2 Drilling techniques ............................................................................................................. 11

4 Data release 4 – drill core rock property measurements .................................................................... 16
   4.1 Previous Stavely Project releases .................................................................................. 16
   4.2 Drill core rock property measurements ........................................................................ 16

5 Data included in this release ............................................................................................................ 17

Acknowledgements ................................................................................................................................ 18

References ............................................................................................................................................. 19
Executive summary

The Stavely Project is a collaboration between Geoscience Australia and the Geological Survey of Victoria. During 2014 fourteen pre-competitive stratigraphic drill holes were completed in the prospective Stavely region in western Victoria in order to better understand subsurface geology and its potential for a variety of mineral systems. The Stavely region hosts several belts of poorly-exposed Cambrian volcanic and intrusive rocks, visible largely only in aeromagnetic data, which have similarities to those found in modern subduction-related tectonic settings. Mineralisation associated with porphyry Cu-Au and volcanic-hosted massive sulphide mineral systems is known where these rocks are exposed around Mount Stavely and the Black Range. However, despite a history of mineral exploration dating back to the late 1960s, significant economic deposits are yet to be discovered, and the Stavely region remains a greenfields terrane. Given the geological setting and known mineral potential, opportunity exists for the discovery of large mineral systems beneath extensive, but relatively thin, younger cover.

The Stavely Project aims to provide the framework for discovery in the Stavely region primarily through the acquisition and delivery of pre-competitive geoscientific data. This includes the completion of pre-competitive stratigraphic drill holes in order to test regional geological interpretations and recover material for detailed lithological, petrophysical, geochemical and geochronological analysis. The results will assist in understanding the mineral systems potential of the Stavely region under cover. This report describes the scanning methods and procedures used to measure rock properties (density, magnetic susceptibility, P-wave velocity, resistivity and natural gamma) of the diamond core from thirteen of the fourteen Stavely Project stratigraphic drill holes. A brief summary of core quality, generalised lithologies and petrophysical responses, together with associated metadata for each scanned drill hole is presented, along with visual logs of the petrophysical data. Processed petrophysical data are provided for download with this report. Analytical methods for each of the petrophysical properties measured are also documented.
1 Introduction

1.1 Project Background

Sporadic historical mineral exploration from the 1960s to the 1990s within and around exposed portions of Cambrian volcanic rocks in the Stavely region of western Victoria resulted in the identification of Cu, Au and base metal mineralisation (e.g. Seymon et al., 2009). More recent research undertaken by universities and government has suggested that some of the Cambrian volcanic rocks are fault-slices of a large, mostly-buried continental margin magmatic arc system – the Stavely Arc. The Stavely Arc is named after the Mount Stavely Belt, which hosts Cambrian igneous rocks of arc affinities and includes the Mount Stavely Volcanic Complex (Crawford and Keays, 1978; Buckland, 1987). The Cambrian volcanic and intrusive rocks of the Stavely Arc have potential to host world-class magmatic-hydrothermal ore deposits. The aim of the Stavely Project is to further encourage and support efficient mineral exploration of the Stavely Arc, by better delineating its distribution and internal geological variation, and characterising mineralisation styles and context.

Crawford and Keays (1978) were the first to describe the Cambrian igneous rocks exposed in western Victoria as having a calc-alkaline character, with the mineralogy and geochemistry of the rocks at Mount Stavely, in particular, suggestive of formation in a magmatic arc-style tectonic setting. Since then several workers have drawn comparisons between the exposed Cambrian volcanic rocks of western Victoria and the Mount Read Volcanics of western Tasmania, the latter of which hosts world class volcanic-hosted massive sulphide (VHMS) deposits (Crawford et al., 1996; Crawford et al., 2003). A range of tectonic settings for the origin of the igneous rocks in western Victoria have been proposed, each with implications for regional metallogeny.

In 2009, the Geological Survey of Victoria (GSV), in collaboration with Geoscience Australia (GA) and AuScope, designed and acquired regional-scale deep crustal seismic reflection transects across western Victoria. The project results supported the interpretation of the Cambrian igneous rocks exposed around Mount Stavely, in the Black Range, and in several belts buried beneath younger sedimentary rocks, as fault slices of the Stavely Arc, which developed above a west-dipping convergent continental margin during the Cambrian. Seismic reflection data imaged an apparent arc edifice remaining largely intact beneath the Stavely region, the upper parts of which have been thrust to the surface.

The setting was interpreted to have the potential to host significant base metal and precious metal deposits, including porphyry and related mineral systems. In addition, it was recognised that the apparent strike extent of individual volcanic belts continues to the north of known occurrences and that historic mineral exploration had not adequately tested the volcanic rocks under cover. In 2011, the Willaura Project was established by the GSV to evaluate the Cu potential of the southern extent of the Grampians-Stavely Zone in the vicinity of exposed Mount Stavely Volcanic Complex rocks (Cayley et al., in prep. a). In 2013, GA and the GSV initiated the Stavely Project in order to evaluate the mineral potential of the new search space identified below younger cover throughout the Stavely region and build and expand on the key findings of the Willaura Project.

The Stavely Arc now replaces the informal and preliminary term ‘Miga Arc’. This term is now abandoned.
The Stavely Project area comprises approximately 20,000 km² (Figure 1.1). It includes at least eight volcanic belts and the Dimboola Igneous Complex, which extends north from Horsham beyond the project area into far north-west Victoria (Figure 1.2). The volcanic belts are separated by wider regions of deformed Cambrian and Ordovician to Silurian sedimentary rocks, intruded by Cambrian and Devonian intrusive rocks, and are also buried by cover rocks of variable thicknesses. The cover rocks include Mesozoic-Cenozoic fill of the Murray and Otway basins and Cenozoic lavas of the Newer Volcanic Group. While a combination of existing exposure, regional geophysics, historical open file drilling, and deep seismic reflection transects has allowed the broad delineation of these volcanic belts under younger cover, the buried parts of the Stavely Arc remain largely untested for their mineral systems potential.

1.2 Geography

The Stavely Project area is located in western Victoria, south-eastern Australia, approximately 230-300 km west and northwest of Melbourne (Figure 1.1). The regional centres of Hamilton and Horsham are located in the south and within the centre of the project area, respectively (Figure 1.3). The project area has generally very low relief, with the only exceptions being the Grampians Ranges and Mount Arapiles, which rise above the plains and effectively mark the western end of the Great Dividing Range. North of the divide, the Wimmera River flows past the Grampians National Park and through Horsham towards Lake Hindmarsh. South of the divide, the Glenelg River flows from its origins within the Grampians Ranges, toward the Southern Ocean. In the south of the project area, the Hopkins River flows through Wickliffe and Chatsworth towards the ocean. Many streams in the region are ephemeral and are often dry for long periods. Dryland farming (crops and livestock) comprise large portions of the project area. The Little Desert and Wyperfeld national parks border the project area to the north.

1.3 Mineral exploration in the Stavely region

Mineral exploration around the exposed belts of Cambrian volcanic rocks began in 1969 when Western Mining Corporation Limited commenced stream sediment and soil geochemical sampling (e.g. Clappison, 1972). Continued exploration by Duval Mining Limited (formerly Pennzoil) followed up on some of the weak geochemical anomalies in 1975, and had quick success with the discovery of gossanous float containing elevated Cu. Follow-up diamond drilling of anomalies within the Mount Stavely Belt discovered stringer chalcopyrite mineralisation in tuffs, now known as the Wickliffe Prospect (Figure 1.4). Diamond drill hole WICKLIFFE NO. 6 terminated in hydrothermally-altered quartz porphyry, tentatively correlated with the intrusive Laikaldamo Porphyry (Ramsay, 1983). Soil geochemistry, geophysics, shallow rotary and deeper diamond drilling was successful in identifying additional mineralised quartz-feldspar porphyries at Junction and Thursdays Gossan (Roberts, 1982; Buckland, 1987; Figure 1.4). Further mineral exploration by subsequent companies in the 1990s discovered several additional occurrences of VHMS and porphyry-style mineralisation, including a Cambrian diorite (now referred to as the Lexington Prospect) outside of the Mount Stavely Belt (Figure 1.4).

Northeast of Balmoral, minor placer and hard-rock Au was first discovered in the late nineteenth century, associated with poorly-exposed igneous rocks exposed in valleys which have been eroded through overlying sedimentary rocks of the Grampians Group. These igneous rocks are now included within the Black Range Belt (Figure 1.2). Exploration in the region began in earnest in the late 1960s and several Au and base metal prospects were discovered aligned along the length of the volcanic belt. The most promising prospect identified was the McRaes Prospect (now referred to as the Eclipse Prospect; Figure 1.4) where anomalous Au, Zn, Pb, Cu and Ag is associated with hydrothermally-altered mafic to intermediate volcanic rocks.
A case history study in the late 1990s (Rajagopalan, 1999) detailed Cu-Mo-Au porphyry mineralisation at Mount Stavely and argued that deep weathering had compromised some of the early geochemical exploration and that only the shallow levels of the system had been tested. Although supergene chalcocite mineralisation had been defined at prospects such as Thursdays Gossan, shallow drilling campaigns targeting geochemical anomalies had often failed to penetrate leached in situ regolith and consequently yielded ambiguous results. Limited investigation of the underlying hypogene mineralisation occurred with most drill holes terminating in variable Cu mineralisation associated with hydrothermal alteration. Due to remaining uncertainty over the geological context, exploration of the mineralised systems at depth was not undertaken.

Recent reinterpretation of historic diamond drill core from the early exploration campaigns in the Mount Stavely Belt suggests that porphyry intersections represent dykes that have intruded into the host volcanic rocks, and that large porphyry bodies of potential economic interest may exist at depth and remain untested (Taylor et al., 2014). A similar problem also exists in the Black Range Belt. Here, insufficient drill testing of known mineralisation, as well as geological uncertainty and the presence of barren Silurian-age Grampians Group cover, has impeded mineral exploration across much of the region.

1.4 The Stavely Project

Despite a relatively long history of mineral exploration in the exposed portions of the Cambrian volcanic rocks, the Stavely region remains a greenfields terrane with the opportunity for significant mineral discoveries, especially below younger cover. The Stavely Project was established in order to provide the fundamental framework for the evaluation and discovery of mineral systems in the Stavely region using a mineral systems-based approach. The Stavely Project is a collaborative program between GA and the GSV and forms part of the broader UNCOVER Initiative (Australian Academy of Science, 2012) and the National Mineral Exploration Strategy (COAG, 2012), which seeks to address the challenges of greenfield mineral exploration in areas of Australia under younger cover.

The Stavely Project aims to provide the framework for exploration risk reduction and discovery in the Stavely region through four key objectives:

1. Characterise subsurface geology and recognise favourable geological environments where major mineral systems may have been active;
2. Identify key elements that demonstrate mineral systems potential;
3. Understand the depth and nature of cover; and
4. Deliver new pre-competitive data and concepts for industry, presenting the evidence for mineral systems potential in greenfields areas under cover.

In addition to the compilation and review of historical geoscientific data for the region, the objectives outlined above were addressed through the acquisition of pre-competitive data, including the completion of a stratigraphic drilling program to test regional geological interpretations and recover samples for lithological, petrophysical, geochemical and geochronological analyses. Site-specific geophysical data acquisition tested the thickness and geophysical properties of cover at selected drill sites (Meixner et al., in prep.). The results of the stratigraphic drilling program will help to better define the margins of the Grampians-Stavely Zone and give further insight into the context, origin and timing of regional mineral systems and aid in future exploration targeting.
Figure 1.1: Location of the Stavely region and structural geological zones of Victoria. Figure adapted from VandenBerg et al. (2000).
Figure 1.2: Known and interpreted volcanic belts of the Stavely Arc. The image is a partially-transparent histogram-equalised pseudocolour layer of the tilt-angle total magnetic intensity (TMI) reduced to the pole (RTP), overlain on a 3-30 km band pass filtered, histogram-equalised pseudocolour layer of TMI (RTP). Blue colours indicate lower magnetic intensity and phase angle values; red colours indicate higher magnetic intensity and phase angle values.
Figure 1.3: Location of the Stavely Project area and significant geographical features.
Figure 1.4: Location of currently known mineral prospects within the Stavely Project area.
2 Geological overview

The Grampians-Stavely Zone (Figure 1.1) lies at the eastern edge of the Cambrian Delamerian Orogen in western Victoria (VandenBerg et al., 2000; Crawford et al., 2003), with the adjacent Stawell Zone forming a complex hybrid transition to the Lachlan Orogen further east (Miller et al., 2005; Cayley et al., 2011; Cayley et al., in prep. b). The interpreted Stavely Arc within the Grampians-Stavely Zone outcrops as a number of narrow north-trending belts of mafic to felsic igneous rocks at Mount Stavely, Mount Dryden, Mount Elliot, and in the Black Range region (Figure 1.2). These were first described during reconnaissance geological mapping of western Victoria in the nineteenth century (Krause, 1873). The belts of igneous rocks are separated by terrigenous deep marine low-grade sedimentary rocks of the Glenthompson Sandstone (Nargoon Group; VandenBerg et al., 2000). A key characteristic of the Cambrian rocks within the Grampians-Stavely Zone is their low (prehnite-pumpellyite facies) metamorphic grade. This contrasts markedly with amphibolite facies metamorphic rocks in the adjacent Glenelg (Gray et al., 2002; Morand et al., 2003) and Stawell (Cayley and Taylor, 2001; Phillips et al., 2002) zones, which lie either side of the region (Figure 1.1).

Early assignment of a Cambrian age for the igneous rocks exposed at Mount Stavely and in the Black Range region was based on comparison with similar rocks in central Victoria from which Cambrian fossils had been recovered (Thomas, 1939). Subsequently, geochronology (Bucher, 1998; Stuart-Smith and Black, 1999; Whelan et al., 2007; Lewis et al., 2015) has confirmed Cambrian ages ranging from 510 Ma to 500 Ma for parts of the Mount Stavely Volcanic Complex. The other volcanic belts in the region currently remain undated.

In the south of the Stavely Project area, the Stavely Arc comprises five individual, relatively narrow (3-8 km) north-northwest-trending volcanic belts (Figure 1.2), which from east to west have been termed the Mount Dryden (190 km strike length), Mount Elliot (25 km strike length), Mount Stavely (80 km strike length), Bunnugal (65 km strike length), and Boonawah (105 km strike length) belts. The Mount Dryden and Mount Stavely belts are directly linked by an oblique series of sub-parallel west-to-northwest-trending, faulted volcanic belts, including the Mount Elliot Belt. The Mount Stavely and Bunnugal belts also converge north of Glenthompson. These volcanic belt linkages suggest formation in a contiguous volcanic arc.

Recent mapping by the GSV has identified a swarm of mafic sills intruding into the Glenthompson Sandstone west of the Mount Stavely Belt. These sills may also represent part of the Stavely Arc package. In addition, scattered occurrences of tholeiitic to boninitic lavas also occur throughout the Grampians-Stavely Zone. These may represent igneous rocks related to the ~600 Ma breakup of Rodinia or the later (~520-500 Ma) convergence and deformation associated with the Delamerian Orogeny (Münker and Crawford, 2000; Miller et al., 2005). Rare ultramafic rocks consisting of serpentinised peridotite (e.g. Williamsons Road Serpentinite) also occur in narrow fault slices amongst the other rock packages.

The Stavely Arc, underlying rocks, and overlying Nargoon Group sediments were folded, faulted, and locally tilted to sub-vertical attitudes at around 500 Ma during the Delamerian Orogeny (Crawford et al., 2003). The timing of deformation is constrained by large, post-tectonic, sub-circular intrusions of the Cambrian Bushy Creek Igneous Complex (489 ± 7 Ma; Stuart-Smith and Black, 1999), which intrude deformed Glenthompson Sandstone and truncate the mafic sills west of Mount Stavely (Crawford et al., 2003). A number of dacitic porphyries (both barren and mineralised) are known near
Mount Stavely and occur both within and external to the volcanic belts (Skladzien et al., 2015). Recent studies suggest that the mineralised porphyry intrusions may share some geochemical affinities with parts of the Bushy Creek Igneous Complex and hence may be associated with the latest pulses of magmatism in the Stavely Arc (Taylor et al., 2014). Recent dating of the mineralised, informally named Victor Porphyry, within the Mount Stavely Belt, yielded an igneous crystallisation age of approximately 500 Ma (Lewis et al., 2015).

The volcanic belts of the Black Range area lie to the north of the Grampians, including, from east to west, the Glenisla, Black Range and Tyar belts (Figure 1.2). These are typically 2-3 km in width and 18-30 km in strike length. These belts converge in the south beneath a region covered by Early Devonian volcanic rocks (Rocklands Volcanic Group), and are intruded by post-tectonic granite (likely Devonian in age). Further north of the Grampians a highly magnetic package of igneous rocks of unresolved affinity lies entirely under younger cover, including rocks assigned to the Dimboola Igneous Complex (VandenBerg et al., 2000; Crawford et al., 2003; Figure 1.2).

Regional-scale deep seismic reflection data suggest that the Stavely Arc rocks exposed in the Mount Stavely Belt and in the Black Range region overlie a crest of a crustal-scale, triangular-shaped region of variably reflective crust (Cayley et al., in prep. b). This is interpreted to be the buried, but largely intact, remnants of the Stavely Arc, developed on older rocks related to the rifted east Gondwana margin. The volcanics exposed at Mount Stavely, in the Black Range, and at Mount Dryden are all interpreted to be thrust slices of the underlying Stavely Arc system (Cayley et al., in prep. b).

The outcropping Mount Stavely Volcanic Complex in the Mount Stavely Belt (Figure 1.2) comprises interbedded subaqueous tuffaceous and volcanioclastic rocks, and as a whole is interpreted to be overlain by deep marine turbiditic rocks of the Glenthompson Sandstone (Buckland, 1987). The association of the Mount Stavely Volcanic Complex with deep marine sedimentary rocks led to the interpretation of a post-collisional rift sequence erupted subsequent to an arc-continent collision event, akin to the Mount Read Volcanics of western Tasmania (e.g. Crawford, 1988; VandenBerg et al., 2000; Crawford et al., 2003). Other early interpretations of the overall tectonic setting of the Mount Stavely Volcanic Complex envisaged a Gondwanaland continental margin setting (Crawford, 1982). This hypothesis has recently found support in subsequent geochemical (e.g. Kemp, 2003), geochronological (Foden et al., 2006), and crustal geometry (paired metamorphic belts; Miller et al., 2005) studies.

These results led Foden et al. (2006) to question earlier arc-continent collisional models advocated for the Stavely Arc. Foden et al. (2006) instead suggested a west-dipping continent-directed subduction zone. Geophysical (seismic and magnetotelluric) data presented by Cayley et al. (Cayley et al., 2011; Cayley et al., in prep. b) and Robertson et al. (2015) also argue for a convergent continental arc setting above a west-dipping subducting slab. A variant on this interpretation was proposed by Gibson et al. (2011) who argued for initial east-dipping subduction, intra-oceanic arc accretion, and a subsequent flip in subduction polarity resulting in emplacement of the Stavely Arc above a west-dipping continental margin.

The Cambrian rocks are overlain by the Late Ordovician- to Silurian-aged, fluvial to shallow marine siliciclastic rocks of the Grampians Group (Cayley and Taylor, 1997; Miller et al., 2001; Cayley et al., 2011). In some places the contact is unconformable, but in most places the contact is faulted and or sheared, and the Grampians Group sequence contains significant structural complexity in its own right (Cayley and Taylor, 1997; Miller et al., 2001). Although this group is thickest and most structurally complex close to the eastern edge of the Grampians-Stavely Zone, overall the Grampians Group is much thinner than previously assumed, especially in the regions surrounding the main mountain ranges (Cayley and Taylor, 1997). Silurian deformation associated with the overlying Grampians
Group has affected the underlying Cambrian rocks in places (Cayley and Taylor, 1997, 2001; Morand et al., 2003), and has resulted in the truncation, offset and reorientation of fault slices of the Stavely Arc. Using Grampians Group deformation history as a template, the underlying Cambrian rocks can be undeformed to show a simpler pre-Silurian configuration, including restoration of the now fragmented porphyry and alteration systems contained within the volcanic belts.

The Grampians Group and its Cambrian basement are intruded by numerous Late Silurian to Early Devonian felsic intrusives, including the Dwyer Granite, Mirranatwa Granite, Bullawin Porphyry, Mafeking Suite and Duchembeagara Granite (e.g. see VandenBerg et al., 2000). These are comagmatic with the Rocklands Volcanic Group (Simpson, 1997) which lies to the west of the Grampians Ranges.

Since the Devonian, the Grampians-Stavely Zone has remained one of the most tectonically stable parts of Australia (Foster and Gleadow, 1992). The Stavely Arc was buried beneath Nargoon Group sediments in the Cambrian and subsequently by Grampians Group, and has since experienced relatively minimal uplift and erosion. This accounts for the relatively high, upper-crustal level of preservation of much of the Cambrian geological system. It is likewise expected that related mineral systems will also remain preserved.

Today, the Cambrian bedrock of the Grampians-Stavely Zone is poorly exposed. Key areas of outcrop are at Mount Stavely, as a string of isolated hills near Mount Dryden, in the vicinity of Mount Elliot and Yarram Park, and as poor outcrops in the Black Range region west of the Grampians. The main Grampians Ranges and National Park overlies the centre of these outcrops. Further south, aeromagnetic and gravity data allow the Cambrian bedrock and its intermittent veneer of Grampians Group to be traced beneath thin basalt lava flows of the Newer Volcanic Group, and beneath the Otway Basin.

To the north, geophysical and historical drill hole data allow the Cambrian bedrock to be traced north beneath the Murray Basin. The Murray Basin is a Cretaceous to Recent intracratonic sag basin that hosts world-class heavy mineral sand deposits (Olshina and van Kann, 2012), and gradually attains thicknesses of several hundred metres (McLean, 2010). The extremely gentle dip of the Murray Basin means that over 200 km strike-length of the Cambrian bedrock of the Grampians-Stavely Zone lies within 200-300 m of the present-day surface and could be explored using modern mineral exploration techniques.
3 Overview of pre-competitive stratigraphic drilling in the Stavely Project area

Pre-competitive stratigraphic drill holes are a key component to building an understanding of the geology and mineral systems potential of the Stavely region. Fourteen pre-competitive stratigraphic drill holes, for a total of 2708.5 m, were completed in order to test regional geological interpretations, determine the depth and nature of cover, and to recover material for subsequent detailed analysis.

3.1 Drilling objectives

The scientific objectives for the holes drilled as part of the Stavely Project are summarised under five key categories (along with the names of specific drill holes):

1. Test the under cover extent of the Mount Stavely Belt, its stratigraphic facing, and its relationship with overlying sedimentary units (STAVELY02 and STAVELY17);
2. Test the presence of interpreted arc-related rocks under cover to define the eastern margin of the Stavely Arc (STAVELY01 and STAVELY16);
3. Test regional structural interpretations to define the western margin of the Stavely Arc (STAVELY05 and STAVELY08);
4. Test for the presence of rocks belonging to the Stavely Arc which have been imaged by magnetic data and determine their character and stratigraphic affinity (STAVELY01, STAVELY02, STAVELY04, STAVELY07, STAVELY11, STAVELY14), as well as target different levels of stratigraphic exposure in the package of north-northwest-trending magnetic rocks previously interpreted as the Dimboola Igneous Complex (STAVELY09, STAVELY10, STAVELY12, STAVELY16); and
5. Characterise the nature of geophysical responses in interpreted arc rocks to test for alteration-related demagnetisation (STAVELY06).

A summary for each drill hole is provided in Table 3.1 and additional information on drill hole rationale and aims is given in Schofield et al. (2015b). The locations of the pre-competitive stratigraphic drill holes are provided in Figure 3.1 and Figure 3.2.

3.2 Drilling techniques

Pre-competitive stratigraphic drilling as part of the Stavely Project had the aim of maximising core recovery, including through unconsolidated cover. In order to ensure maximum core recovery, sonic and diamond drilling techniques were used. In general, drilling of sonic pre-collars was used where unconsolidated Murray Basin sediments overlay basement rocks, while diamond drilling was used in order to complete basement tails (typically ~30-50 m length). Diamond drilling was used solely where bedrock (including Newer Volcanic Group basalt) outcropped near the surface. Information on the drilling type used at each drill hole is given in Table 3.1.
Table 3.1: Drill hole collar locations, drilling aims, basement lithology intersected, and associated data collected for drill holes completed as part of the Stavely Project.

<table>
<thead>
<tr>
<th>Hole ID</th>
<th>Drilling type</th>
<th>Latitude (GDA94)</th>
<th>Longitude (GDA94)</th>
<th>Target</th>
<th>Total depth (m)</th>
<th>Basement lithology (generalised)</th>
<th>Rock property data acquired</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAVELY01</td>
<td>Diamond</td>
<td>-38.018</td>
<td>142.878</td>
<td>Possible Mount Stavely Volcanic Complex or Mount Dryden Volcanics equivalent.</td>
<td>249.5</td>
<td>Amphibolite</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY02</td>
<td>Diamond</td>
<td>-37.902</td>
<td>142.712</td>
<td>Extension of the Mount Stavely Belt beneath Grampians Group cover.</td>
<td>159.5</td>
<td>Mafic volcanics (overlain by Grampians Group)</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY03</td>
<td>Hole cancelled</td>
<td>-37.462</td>
<td>142.186</td>
<td>Demagnetised zone within an otherwise magnetic belt of interpreted Cambrian volcanic rocks.</td>
<td>Hole cancelled</td>
<td>Hole cancelled</td>
<td>Hole cancelled</td>
</tr>
<tr>
<td>STAVELY04</td>
<td>Sonic, diamond</td>
<td>-37.164</td>
<td>142.251</td>
<td>Magnetic package of rocks interpreted as Cambrian volcanic rocks.</td>
<td>102.8</td>
<td>Mafic volcanics</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY05</td>
<td>Sonic, diamond</td>
<td>-37.097</td>
<td>142.016</td>
<td>Test for the presence of high-grade metamorphic rocks of the Glenelg Zone to validate structural interpretations.</td>
<td>71.5</td>
<td>Sandstone and siltstone</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY06</td>
<td>Sonic, diamond</td>
<td>-37.050</td>
<td>142.274</td>
<td>Demagnetised zone within an interpreted intrusive rock.</td>
<td>117.7</td>
<td>Quartz diorite</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY07</td>
<td>Sonic, diamond</td>
<td>-36.994</td>
<td>142.323</td>
<td>Magnetic package of rocks interpreted as Cambrian volcanic rocks.</td>
<td>501.6</td>
<td>Intermediate to felsic volcanics</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY08</td>
<td>Sonic</td>
<td>-36.910</td>
<td>141.670</td>
<td>Test for the presence of high-grade metamorphic rocks of the Glenelg Zone to validate structural interpretations.</td>
<td>122.0</td>
<td>Foliated biotite granite</td>
<td>No</td>
</tr>
<tr>
<td>STAVELY09</td>
<td>Sonic, diamond</td>
<td>-36.800</td>
<td>142.159</td>
<td>Magnetic package of rocks interpreted as Cambrian volcanic rocks and to test the lower stratigraphic levels of a north-northwest-trending package of rocks previously interpreted as Dimboola Igneous Complex.</td>
<td>165.6</td>
<td>Mafic volcanics and quartz gabbro</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY10</td>
<td>Sonic, diamond</td>
<td>-36.804</td>
<td>142.130</td>
<td>Magnetic package of rocks interpreted as Cambrian volcanic rocks and to test the lowest stratigraphic level of a north-northwest-trending package of rocks previously interpreted as Dimboola Igneous Complex.</td>
<td>107.4</td>
<td>Serpentine</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY11</td>
<td>Sonic, diamond</td>
<td>-36.767</td>
<td>141.967</td>
<td>Test a weak linear magnetic feature for the presence of a northern extension to the Black Range Belt.</td>
<td>164.6</td>
<td>Sandstone and siltstone</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY12</td>
<td>Sonic, diamond</td>
<td>-36.709</td>
<td>142.153</td>
<td>Magnetic package of rocks interpreted as Cambrian volcanic rocks and to test the upper stratigraphic levels of a north-northwest-trending package of rocks previously interpreted as Dimboola Igneous Complex.</td>
<td>180.5</td>
<td>Intermediate volcanics and volcanioclastics</td>
<td>Yes</td>
</tr>
<tr>
<td>Hole ID</td>
<td>Drilling type</td>
<td>Latitude (GDA94)</td>
<td>Longitude (GDA94)</td>
<td>Target</td>
<td>Total depth (m)</td>
<td>Basement lithology (generalised)</td>
<td>Rock property data acquired</td>
</tr>
<tr>
<td>----------</td>
<td>---------------</td>
<td>-----------------</td>
<td>------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------</td>
<td>-------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>STAVELY13</td>
<td>Hole cancelled</td>
<td>-36.424</td>
<td>141.845</td>
<td>Test an elongate magnetic feature to determine its character and stratigraphic affinity.</td>
<td>Hole cancelled</td>
<td>Hole cancelled</td>
<td>Hole cancelled</td>
</tr>
<tr>
<td>STAVELY14</td>
<td>Sonic, diamond</td>
<td>-36.437</td>
<td>141.655</td>
<td>Test a gravity feature for the presence of Cambrian volcanic rocks.</td>
<td>339.0</td>
<td>Sandstone and siltstone</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY15</td>
<td>Hole cancelled</td>
<td>-36.771</td>
<td>141.970</td>
<td>Magnetic package of rocks interpreted as Cambrian volcanic rocks and to test the upper stratigraphic levels of a north-northwest-trending package of rocks previously interpreted as Dimboola Igneous Complex.</td>
<td>Hole cancelled</td>
<td>Hole cancelled</td>
<td>Hole cancelled</td>
</tr>
<tr>
<td>STAVELY16</td>
<td>Sonic, diamond</td>
<td>-36.265</td>
<td>141.921</td>
<td>Magnetic package of rocks interpreted as Cambrian volcanic rocks and to test the upper stratigraphic levels of a north-northwest-trending package of rocks previously interpreted as Dimboola Igneous Complex.</td>
<td>357.7</td>
<td>Polymictic volcanic breccia</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY17</td>
<td>Diamond</td>
<td>-37.683</td>
<td>142.641</td>
<td>Intersect the contact between the Glenthompson Sandstone and the Mount Stavely Volcanic Complex in the Mount Stavely Belt to determine nature of contact and stratigraphic facing.</td>
<td>156.0</td>
<td>Sandstone and siltstone</td>
<td>Yes</td>
</tr>
<tr>
<td>STAVELY18</td>
<td>Hole cancelled</td>
<td>-37.684</td>
<td>142.652</td>
<td>Intersect the contact between the Glenthompson Sandstone and the Mount Stavely Volcanic Complex in the Mount Stavely Belt to determine nature of contact and stratigraphic facing.</td>
<td>Hole cancelled</td>
<td>Hole cancelled</td>
<td>Hole cancelled</td>
</tr>
<tr>
<td>STAVELY19</td>
<td>Hole cancelled</td>
<td>-37.642</td>
<td>142.656</td>
<td>Locate fresh volcaniclastic Glenthompson Sandstone equivalent at-depth for geochronological and geochemical analysis.</td>
<td>Hole cancelled</td>
<td>Hole cancelled</td>
<td>Hole cancelled</td>
</tr>
</tbody>
</table>
Figure 3.1: Location of drill holes drilled as part of the Stavely Project shown on a background of reduced to pole total magnetic intensity, where red is high and blue is low.
Figure 3.2: Location of drill holes drilled as part of the Stavely Project shown on a background of Bouguer anomaly gravity image where red is high and blue is low.
4 Data release 4 – drill core rock property measurements

This report describes the acquisition of rock properties acquired on drill core obtained for stratigraphic drill holes completed as part of the Stavely Project. Future data releases will subsequently be released as data become available. The datasets are available digitally from GA and the GSV at http://www.ga.gov.au/ and also via http://www.energyandresources.vic.gov.au/. Rock property data are also available for download from the Geoscience Australia rock properties database (see Section 5).

4.1 Previous Stavely Project releases

A description of drilling techniques and data collected in the field, either during or immediately following drilling, is given in Schofield et al. (2015a). These data (see Barton et al., 2015) include drill hole collar information, operational metadata and daily drilling reports, drill core photographs, down-hole surveys, down-hole wireline geophysical logging results, down-hole temperature logging results, down-hole AutoSonde™ gamma data, Lab-at-Rig® X-ray fluorescence data, diamond drill core recovery percentages, and handheld magnetic susceptibility measurements on the drill core. HyLogger™ data collected on all Stavely Project drill holes, including both sonic and diamond drill core, is described in Thomas et al. (2015) along with the methods and procedures used. Lithological logs for drill holes completed as part of the Stavely Project are given in Schofield et al. (2015b).

4.2 Drill core rock property measurements

Accurate 3D geological models form an essential component of effective mineral exploration under cover. A key input into these models is knowledge of the petrophysical attributes of the subsurface geology. In particular, accurate density and magnetic susceptibility data are essential to develop robust 3D geological models from gravity and magnetic potential field data. Electrical property data (e.g. conductivity and resistivity) are also essential for inverting airborne electromagnetic and magnetotelluric data. In conjunction with down-hole geophysical wireline logs acquired immediately following drilling as part of the Stavely Project (see Schofield et al., 2015a), laboratory petrophysical measurements of the recovered HQ3 and NQ3 diamond drill core provide vital input data from which to build improved geological understanding of the Stavely Project area.

The Stavely Project provided an opportunity to draw upon the expertise and facilities of the AuScope Australian Geophysical Observing System (AGOS) Subsurface Observatory at the University of Melbourne. A proposal entitled ‘Petrophysical measurements of cover and basement materials from the Stavely Zone, western Victoria’ was submitted and accepted by AGOS to undertake petrophysical logging of Stavely Project drill core using the AGOS Geotek Multi-Sensor Core Logger (MSCL) equipment.

Petrophysical properties measured by the MSCL for the HQ3 and NQ3 diamond drill core from the Stavely Project stratigraphic drill holes included density, magnetic susceptibility, P-wave velocity, resistivity and natural gamma. Core thickness determinations were also completed. These data compliment the commercially-acquired geophysical wireline logging of the drill holes. A detailed description of general MSCL scanning methodology and analysis, as well as specific details for 13 Stavely Project stratigraphic drill holes scanned is presented in the report prepared by AGOS in Appendix 1.
5 Data included in this release

This data release includes petrophysical rock property data acquired from drill core scanned by the MSCL at the AGOS Subsurface Observatory at the University of Melbourne. A report completed by AGOS outlining scanning and analysis methodology and associated metadata, summary graphic logs and histogram plots for each of the 13 drill holes scanned, together with the processed data, is included as digital appendices to this report. The following data are included in this release:

- **Appendix 1: AGOS report.** Report on petrophysical data acquisition prepared for GA and the GSV by AGOS.
- **Appendix 2: Petrophysical data.** Rock property data including density, magnetic susceptibility, P-wave velocity, resistivity, natural gamma and core thickness acquired for diamond drill core in comma separated values (.csv) format.

The data are also available from the Geoscience Australia rock properties database (http://www.ga.gov.au/scientific-topics/disciplines/geophysics/rock-properties). Commercially-acquired geophysical wireline logging data are given in Barton et al. (2015).
Acknowledgements

Scanning of diamond drill core was carried out by Philomena (Min) Manifold and Alison Fairmaid. The AGOS report contained in Appendix 1 was prepared by David Belton and Philomena (Min) Manifold. Ken Sherry and Nat Pastro prepared core for shipment to the AGOS facility from the GSV core library. David Higgins prepared thematic maps for the project area. Cameron Cairns and Ian Roach are thanked for their thoughtful reviews of this document, and for QA/QC of the associated data. Mark McLean is thanked for liaising with AGOS staff during core scanning. Ian Roach is thanked for uploading the data to the Geoscience Australia rock properties database.
References


Clappison, R.J.S. 1972. (A) Stavely Area, Victoria, Late E.L. 133 and (B) Black Range Area, Victoria, Late E.L. 134. Western Mining Corporation Limited Report No K/1771. Victorian Geological Survey (Reference ID 31100).


