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A New Method Of Mapping Sub-Volcanic Geology Using Magnetic Data

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ABSTRACT

The Gawler Range Volcanics (GRV) province of the Western Gawler Craton in South Australia is an under-explored area covered by good quality, open file magnetic data. Using these data, a test study was conducted for the government of South Australia to map the thickness of volcanics and sub-volcanic geology over an area of 220km by 75km.The test area was chosen over: the southern margin of the GRV where the thickness of volcanics was unknown, outcropping basement and basement with thin cover. Beneath the volcanic cover, basement configuration is unknown as there are a limited number of holes drilled, with only one penetrating through the volcanics.

The main aim of this study was to map the base of volcanics, depth to sub-volcanic basement and delineation of structures underlying the GRV from the magnetic data. This test was also used to assess our new technique together with other methods concurrently being used to map sub-surface geology, such as passive seismic.

To map base of volcanics and underlying basement, the Automatic Curve Matching (ACM) method was applied to located magnetic data. This method detects magnetic sources within different rock units of the crust, such as volcanics and the underlying basement.

The ACM method was used to analyse and interpret millions of individual magnetic anomalies along profiles, detecting causative magnetic sources providing depth, location, geometry and magnetic susceptibility. To image the GRV in 3D, the high-frequency component of the magnetic field was targeted. The Total Magnetic Intensity (TMI) data was analysed using separate geophysical algorithms to simulate sub-horizontal volcanic lava flows, and to model complex basement geology more effectively. The magnetic susceptibilities detected by ACM indicated the geochemistry of volcanics of different ages. This allowed the imaging of separate lava flows and differentiation of the volcanics from the underlying basement. Using different visualisation techniques for the results from each algorithm, the base of volcanics was mapped along 75km NS profiles, spaced 1km apart over a distance of 220km, covering an area of 16,500km2. The results were gridded, and an image of the base of volcanics was generated.

This procedure was used to map the top of the sub-volcanic magnetic basement. The Proterozoic basement magnetic susceptibilities and the magnetic source distribution pattern, were used as key determinants to interpret the depth to the top of basement. The final results were gridded and an image of the basement configuration was generated.

In some areas, the base of volcanics coincides with the basement, whereas in other areas, there is a difference between the two, which could be due to the presence of sub-volcanic sediments. The results show that the volcanics are on average 700m-900m thick with a very thick section exceeding 3.4km in the east, and around 1.5km in the west of the study area.

The mapped volcanics thickness was validated by comparison with numerous drill holes (intersecting the base of volcanics or terminating within the volcanics). All the results matched the drill-hole data extremely well. After project completion, a passive seismic survey was conducted at the eastern end of the test area, indicating a base of volcanics of about 4km, which further confirms our results.

The results achieved show that this process of mapping sub-volcanic basement can be applied in other volcanic provinces worldwide, and provide valuable and, perhaps, crucial information for mineral and petroleum exploration. Based on the imaged base, thickness and magnetic susceptibilities of volcanics, the magnetic influence of volcanics can be modelled and subtracted from the acquired magnetic data, thus enabling interpretation of magnetic anomalies arising from sub-volcanic crust. This can be done over sedimentary basins where thick volcanics mask seismic signals and prevent mapping of sub-volcanic geology. Our new method can assist solving challenges in sub-volcanic petroleum exploration in India.