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H045

Depth Extent - A Practical Example in Magnetic Depth Estimation

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SUMMARY

Corrections for depth extent, or the thickness of the assumed magnetic body, are critical in obtaining accurate magnetic depth to basement estimates in common exploration environments. However, determination of the correct thickness to depth (T/D) ratio would seem to require a pre-supposition of the approximate depth to basement and magnetic layer thickness.

We show by application to the "Bishop" model that significant improvements in depth to magnetic basement can be made by incorporating a thickness to depth (T/D) ratio in our depth calculations by making reasonable geologic assumptions even when no a-priori knowledge exists as to the appropriate T/D to use. Using basic assumptions of isostasy combined with known geologic information gained through integration with seismic, gravity and well control yields even better results with limited additional effort. Better magnetic depth to basement estimates can have a direct impact in improving regional structural and basin models resulting in an improved understanding of the regional tectonic elements and play characteristics.

Introduction

Previous work (Flanagan and Bain 2012) has shown that corrections for depth extent, or the thickness of the assumed magnetic body, are critical in obtaining accurate magnetic depth to basement estimates in common exploration environments. However, determination of the correct thickness to depth (T/D) ratio would seem to require a pre-supposition of the approximate depth to basement and magnetic layer thickness. As stated by Skilbrei, 1993, “it is usually not possible to interpret the depth extent of magnetic bodies within the basement”. Therefore, it has become normal practice to make the assumption that, if the thickness is significantly larger than the depth to basement, one can use the default parameters defined for bodies of infinite thickness.

We propose that reasonable assumptions can be applied in many geologic environments based on prior knowledge. Regional well, geologic or seismic control for example can be used to define minimum depth to basement with isostatic assumptions or Curie depth being used to define the base or a proxy for the base of the magnetic layer.

We develop a simple isostatic method for estimating the thickness of the magnetic layer that can be applied in areas of passive margins without reference to any input depth to basement control and apply it to the well known Bishop test model (Williams et.al., 2002).

Methodology

To resolve the issue of an appropriate thickness to depth (T/D) ratio we use as an example the concept of isostasy as applied to a relatively simple passive margin. We have taken the approach of using an Airy point by point calculation in its simplest form.

1. Assume an initial un-stretched crust of an appropriate thickness and density (Figure 1).

2. Calculate the depth to basement using the default divisor for your method of choice. Here we apply the tilt-depth divisor of 2, which has been shown to be appropriate only for truly infinite source body thickness (Flanagan and Bain, 2012).

3. Water depth if applicable is assumed to be known. Therefore you can easily calculate depth to base crust, and thus the thickness of crust using Airy isostasy.

4. Using the new calculated crustal thickness one can then generate a new depth divisor from the tilt-depth nomographs previously developed (Flanagan and Bain, 2012) and calculate a thickness corrected depth to basement estimate.

As an illustration we assume a model with initial crustal thickness of 35 km and density of 2.8 g/cm^3, and assume densities for water (1.03 g/cm^3), sediment (2.4 g/cm^3), crust (2.8 g/cm^3), and mantle (3.3 g/cm^3). Simple model tests show the known depth can be estimated within less than 1% within 3-4 iterations.

More complex models assuming a sediment depth/density function or models with a calculated or assumed Curie depth can also be used and achieve similar improved results.

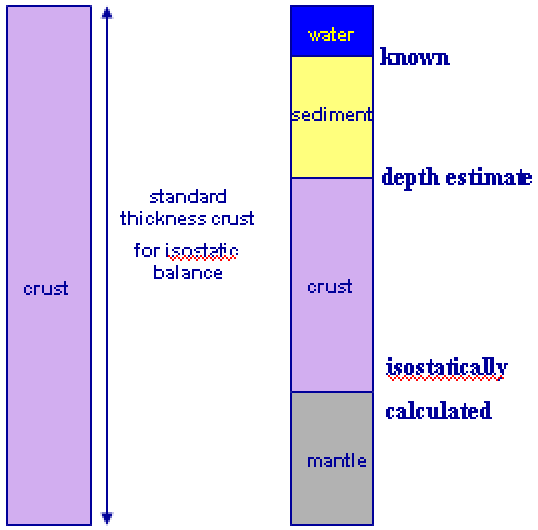
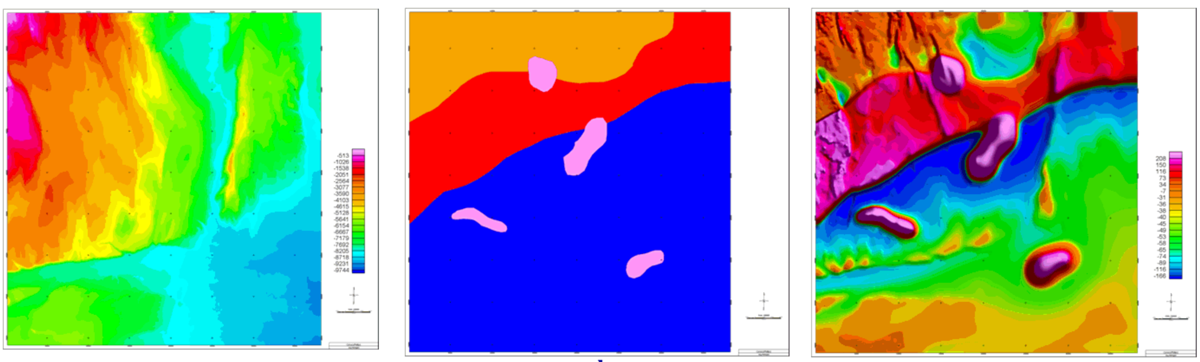


Figure 1 *Isostatic balancing of basement depth for calculation of thickness to depth (T/D).*

Example

As an example we apply the method to the Bishop model (Williams, et.al., 2002). Topographic data for a portion of the volcanic tablelands area north of Bishop, California, USA was up-scaled by a factor of 30 in x, y, and z dimensions and then shifted in z such that the structures are all now sub-surface varying from approximately 100 to 9300 m in depth (Figure 2a). The gravity effect of the resulting basin was then calculated assuming a relatively simple increasing density with depth function. An approximated Moho corresponding to a passive margin was generated by inverting on the base crust to bring the calculated result to a zero level and smoothing the resulting surface with a 300 km low-pass filter to remove local features. A number of isolated intrusions and lithology contacts were digitized to simulate basement intrusions and susceptibility changes (Figure 2b). The magnetic field was then calculated assuming the magnetic crust extended from basement to the Moho (Figure 2c).



a b c

Figure 2 *Bishop model: a) basement surface, b) susceptibility boundaries, c) calculated magnetic field.*

Magnetic depths were calculated from profiles extracted from the calculated magnetic anomaly grid. Profiles were selected to cross anomalies at 90º to avoid the need for strike corrections. Depth estimates were generated using two methods. First, depths were calculated using the default tilt-depth divisor of 2.0, assuming infinite thickness. Second, depths were calculated using the appropriate tilt-depth divisor based on our prior knowledge of thickness to depth (T/D) and width to depth (W/D) for the observed anomalies. Each set of depths was then contoured using minimum curvature with a limited extrapolation (Figure 3). The depths using the correct divisor (Figure 3b) are quite comparable to the known model (Figure 3a). However, it is obvious that the depths using the default divisor (Figure 3c), particularly in the deep areas where the modeled crust is thin, are significantly shallower than the known model.

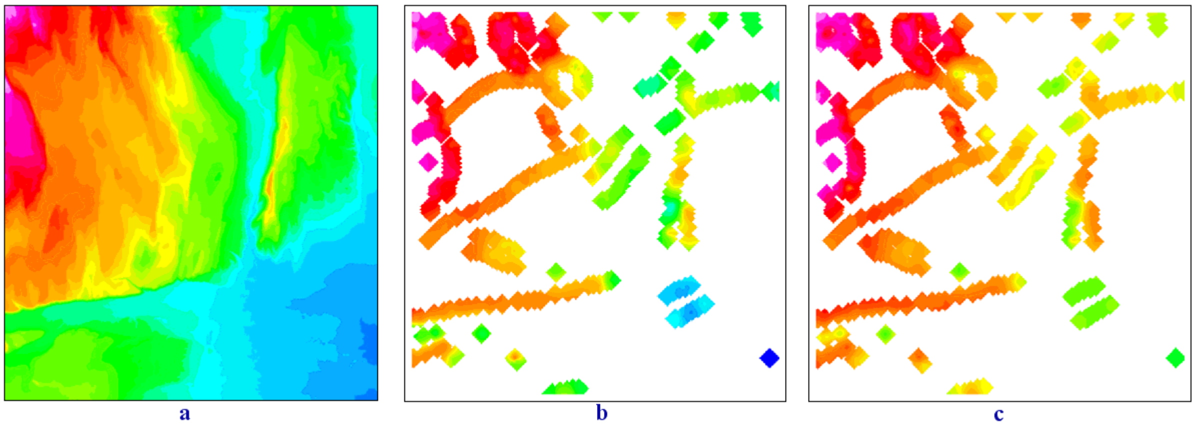


Figure 3 *Bishop model: a) basement surface, b) basement calculated using correct T/D divisor, c) basement calculated using default T/D divisor. Color scale is linear from red (0m) to dark blue (-10000m).*

Making thickness corrections in the manner described above to the basement calculated using the default divisor gives the results shown in Figure 4. It is now difficult to see any difference between the depths using the correct divisor (Figure 4b) and the thickness corrected magnetic depths using the default divisor (Figure 4c).

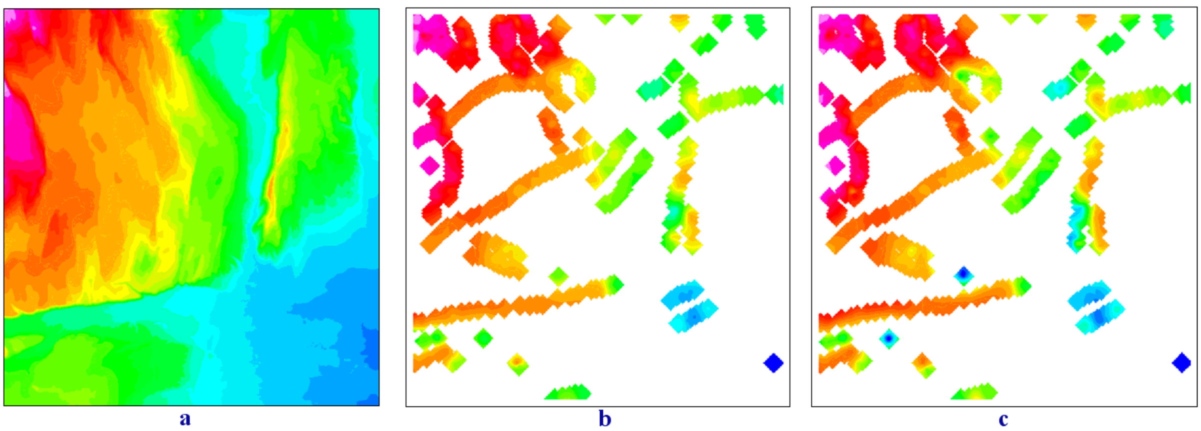


Figure 4 *Bishop model: a) basement surface, b) basement calculated using correct T/D divisor, c) basement calculated using default T/D divisor and applying isostatic correction. Color scale is linear from red (0m) to dark blue (-10000m).*

Here we used a single sediment density of 2.4 g/cm^3 rather than the correct depth-density functions. Other sediment densities, depth-density functions and varying versions of base crust were tested. All showed significant improvement indicating that the method is relatively robust. Even better results should be achieved if known geologic control is incorporated into the thickness assumptions.