This is a text only version for Open-File Report 03-200

Geophysical Identification and Geological Implications of the Southern Alaska Magnetic Trough

By R.W. Saltus[1], T.L. Hudson[2], and F.H. Wilson[3]

2003

[1]U.S. Geological Survey, Denver, CO (saltus@usgs.gov), [2]Applied Geology, Sequim, WA (ageology@olypen.com), [3]U.S. Geological Survey, Anchorage, AK, (fwilson@usgs.gov)

Open-File Report 03-200

Abstract

The southern Alaska magnetic trough (SAMT) is one of the fundamental, crustal-scale, magnetic features of Alaska. It is readily recognized on 10 km upward-continued aeromagnetic maps of the state. The arcuate SAMT ranges from 30 to 100 km wide and extends in two separate segments along the southern Alaska margin for about 1200 km onshore (from near the Alaska/Canada border at about 60 degrees north latitude to the Bering Sea) and may continue an additional 500 km or more offshore (in the southern Bering Sea). The SAMT is bordered to the south by the southern Alaska magnetic high (SAMH) produced by strongly magnetic crust and to the north by a magnetically quiet zone that reflects weakly magnetic interior Alaska crust. Geophysically, the SAMT is more than just the north-side dipole low associated with the SAMH. Several modes of analysis, including examination of magnetic potential (pseudogravity) and profile modeling, indicate that the source of this magnetic trough is a discrete, crustal-scale body. Geologically, the western portion of the SAMT coincides to a large degree with collapsed Mesozoic Kahiltna flysch basin. This poster presents our geophysical evidence for the extent and geometry of this magnetic feature as well as initial geological synthesis and combined geologic/geophysical modeling to examine the implications of this feature for the broad scale tectonic framework of southern Alaska.

Map Showing Crustal-scale Magnetic Domains of Alaska

Contents

Crustal-scale magnetic domain map plotted on 10-km upward-continued aeromagnetic data.

There are many crustal-scale magnetic domains in Alaska (see figure at right and table below). Most of these domains are still recognizable when aeromagnetic data are upward continued to 40 km. Upward continuation is a mathematical procedure for converting measured potential field values (such as aeromagnetics) to those that would be measured at a different altitude. Because the magnitude of simple-source magnetic anomalies decreases with the cube of the distance from the source, upward continuation is an effective low-pass filter that emphasizes broad, and therefore likely deep, features. Alaska may be subdivided into three regional magnetic domains:

1. Southern Alaska - a series of arcuate magnetic domains including the southern Alaska magnetic high and trough.

2. Interior Alaska - a neutral magnetic domain with scattered intermediate wavelength highs, particularly in western Alaska.

3. Northern Alaska - a subdued magnetic character and host to the North Slope deep magnetic high.

The southern region is magnetically distinct from the rest of Alaska. It contains strong magnetic highs and lows that are continuous along strike for more than 1,000 km. These domains correlate with convergent margin tectonostratigraphic terranes including magmatic arcs, deformed flysch belts, and accreted oceanic crust (see table at right).

In this poster we take a closer look at the southern Alaska magnetic trough. How narrowly can we constrain its boundaries and what is it's likely tectonic significance?

Map showing Detailed Geophysical Delineation of the Southern Alaska Magnetic Trough

Contents

This map shows the 10-km-upward-continued magnetic field for southern Alaska. The region of deepest blue to the north of the southern Alaska magnetic high is the location of the southern Alaska magnetic trough (see the "What is a Magnetic Trough?" discussion below for clarification).

Black contour lines of magnetic potential are plotted on the map. We have identified the closed -100 nT-m contour as the southern Alaska magnetic trough (SAMT) boundary. Although the zero contour should theoretically serve as a trough boundary (see panel below), uncertainties regarding the position of absolute zero in the Alaska regional magnetic compilation (or indeed on any regional magnetic compilation), along with the better correspondence of the -100 nT-m contour with the deepest portions of the upward-continued magnetic field, suggest that it is a better choice. The white lines map the maximum gradient of the magnetic potential. These lines provide another estimate of the boundaries of the southern Alaska magnetic trough. Here the northern boundary of the trough is more narrowly determined than the southern boundary (see the discussion in the panel below). The southern boundary of the Alaska magnetic trough is a zone that extends from the -100 nT-m contour to the maximum horizontal gradient line. The area between these two indicator lines may be a zone of transitional crust between the sources of the two domains. Within the map area the southern Alaska magnetic trough can be divided into 3 parts based on the 10-km-upward-continued data; (1) a 40 by 200 km eastern segment with strong magnetic lows, (2) a 30 by 270 km central gap with weaker lows, and (3) a western 70 by 600 km segment with strong lows.

Map showing Geologic Correlation of Southern Alaska Magnetic Trough

Contents

This map depicts the geophysical definition lines over a generalized geologic map. The geologic map was compiled to assist interpretation of regional gravity and magnetic data and their implications for southern Alaska crustal structure. The 1:1,000,000 geologic map is based on Beikman and others (1977a, 1977b). Recent geologic information compiled by Wilson and others (1998) was used to modify the map in some areas. The assemblages (see map legend for detailed descriptions) are combinations of geologic units that together are expected to have generally similar physical properties and similar tectonostratigraphic character.

We make the following observations about the correspondence of the southern Alaska magnetic trough (SAMT) with geologic assemblages:

The western SAMT:

In this section the SAMT is very large: 70-140 km wide, 550 km long, and caused by sources that are 10 or more km thick. This volume of nonmagnetic rocks mostly overlaps the outcrop area of the Alaska Range flysch-like sedimentary rocks (see geologic unit descriptions), but includes other assemblages as well.

More than 300 km of the northern boundary in this area is semiparallel to, but 20 to 40 km north of, the Farewell-Hines Creek fault system. The western 250 km of this boundary strikes south-southwest, semiparallel and within 10 to 20 km of the Big River-Babel River-Lime Village regional lineament. This lineament approximately coincides with the boundary between Kahiltna flysch to the south and Paleozoic sedimentary rocks to the north.

The southern boundary of the magnetic potential low that defines the western SAMT is semiparallel to the northern boundary of the southern Alaska magnetic high (SAMH) but displaced 40 to 60 km north. This 40 to 60 km wide zone between the SAMH and the SAMT includes part of the central SAMT segment where mapping shows smaller geologic elements such as the Chulitna terrane scattered through areas of Kahiltna flysch. Further south, a large magnetic low (with a few local deepseated magnetic highs) in the western Kenai/eastern Lake Clark quadrangles and associated with crystalline rocks of the Peninsular terrane, separates the SAMH from the lowest portion of the SAMT.

In general, it appears that the SAMH and the SAMT may be separated by a transition zone where the crust is mostly made up of nonmagnetic to weakly magnetic sources. The rocks making up these sources appear to be Paleozoic and Early Mesozoic sedimentary, igneous, and metamorphic rocks.

Some specific geologic observations about the western SAMT include (1) K-T igneous rocks in the SAMT are shallow-seated and not crustalscale elements (see profile B-B'), (2) the Kahiltna flysch is the principal nonmagnetic geologic element responsible for the western SAMT (this conclusion implies that the a significant part of the crust in this region is made up of Kahiltna flysch and that this part of the Kahiltna flysch currently rests on a thinned continental basement), (3) the Farewell-Hines Creek fault system is the northern boundary of the Kahiltna flysch although the more gradual magnetic potential gradient on this flank of the SAMT could indicate that this boundary dips north at deeper crustal levels, and (4) the Paleozoic sedimentary rocks south of the Farewell fault in the McGrath quadrangle are probably a thin structural flap over Kahiltna flysch as locally mapped.

The central gap

A gap appears between the western and eastern segments of the SAMT. The western part of this gap coincides with an area south of the Hines Creek fault where Paleozoic and Early Mesozoic sedimentary and igneous rocks are interleaved with Kahiltna flysch. This combination of geologic elements may be the cause of the weaker mag potential of the gap. Therefore, this mix of geologic elements may be a significant crustal feature in this area. In the eastern part of the gap the Denali fault juxtaposes Paleozoic and older(?) metamorphic rocks of the Yukon-Tanana terraine to the north against highly magnetic rocks (including

Triassic basalt and gabbro) of the Wrangellia composite terrane in the SAMH to the south. Within the central gap the aeromagnetic low appears to be entirely due to The eastern SAMT

This large part of the SAMT requires that nonmagnetic sources make up much of the crust from the eastern Mt. Hayes quadrangle to the border with Canada. The SAMT in this area lies 10 to 40 km north of the Denali fault and does not closely coincide with any mapped surface geology. It spatially overlaps various Paleozoic metasedimentary and metaigneous rocks.

Clastic sedimentary rocks of the J-K Nutzotin Mountains sequence and of an unnamed K-T sequence (correlative in part with the Kahiltna flysch) lie south of the deepest portions of the SAMT and the Denali fault in the Nabesna quadrangle, but north of the northern boundary of the SAMH.

What is a Magnetic Trough?

We define a magnetic trough as a region of the Earth's magnetic field where the total field amplitude is too low to be explained as a dipolar lobe from an adjacent region of high magnetic values. A magnetic trough is caused by source rocks that are systematically less magnetic than the rocks in the surrounding regions.

The figure on the right illustrates the magnetic trough concept. The bottom panel of the figure depicts the cross section of a two-dimensional model of a hypothetical magnetic susceptibility distribution. The magenta body has a strong positive magnetic susceptibility (100x10-3 SI) relative to the background level (20x10- 3 SI). The cyan body is not magnetic (susceptibility of 0). North is on the left side of the figure and the Earth's magnetic field inclination is 75 degrees (a typical value for Alaska). The magenta curves in the upper panels are the calculated magnetic and magnetic potential anomalies that result from the magenta body. Similarly the cyan curves show the anomalies that result from the cyan body. The blue curves show the combined effect of the two bodies (i.e., cyan+magenta=blue). The diagonally hatched area is the difference between the two curves - this is the magnetic trough region. The cross-hatched region on the magnetic potential panel shows the region where magnetic potential is negative compared with background values.

To appreciate the difficulty in identifying and interpreting magnetic troughs, compare the edges of the source body (gray dashed lines) with the curves above. Theoretically the maximum gradients in the magnetic potential should give the best estimates of source boundaries. This can be seen from the cyan magnetic potential curve. However, in the two-body case, as illustrated here, the edge of the highly magnetic body has a much stronger influence on the magnetic potential gradients and makes exact determination of the southern boundary of the trough source problematic. The presence of a magnetic potential low is a strong indicator of the magnetic trough, but not of its exact boundaries. The best approach to mapping the source body for the trough is through constrained models.

Figure showing 2D Profile Models

Contents

This panel displays two combined gravity/magnetic models constructed along regional profiles in southern Alaska (locations shown on the large geophysical and geologic maps above). Profile A-A' follows the Trans-Alaska Crustal Transect (TACT) profile, but has been straightened out from the actual transect (which is shown by x's on the geophysical map). For comparison, seismic-based interpretations that fall approximately along this line are also summarized (Grantz and others, 1991; Fuis and others, 1991; 1997; Beaudoin and others, 1994). The TACT profile crosses the central SAMT gap where the trough is absent as a geophysical feature. However, profile A-A' allows us to use the TACT seismic results to calibrate the total crustal thickness and character of the southern Alaska magnetic high so that we may carry these crustal elements over to profile B-B'.

Profile B-B' crosses the northern Cook Inlet. The shallow portion of the model (inset in figure) is tied to shallow industry seismic data calibrated by stratigraphic tops from wells. The deeper portion of profile B-B' appears to be broadly consistent with a teleseismic profile constructed by Seth Moran, USGS (written communication). In the teleseismic model cooler colors (blues) represent higher seismic velocities.

The source body for the southern Alaska magnetic trough is modeled here as a southeastward-thickening wedge that occupies most of the upper crust. Superimposed on the magnetic low values of the trough are short-wavelength magnetic highs with shallow (intrusive) sources. While a very thick (greater than 5 km), low susceptibility body is required to match the magnetic data, the exact form of the body is not well determined. Additional constraints (such as from seismic data or magneto-telluric soundings) will be required to lessen this ambiguity.

Conclusions

· Use of regional magnetic data for crustal analysis requires a combination of processing approaches. Use of the magnetic potential (also known as pseudogravity) is important for evaluating the dipole effect of strongly magnetic regional features and identifying possible magnetic troughs. Magnetic trough boundaries are difficult to map precisely, particularly on their southern flanks (in the northern hemisphere), where steep magnetic gradients from any highly magnetic bodies to the south can dominate the signal.

· The southern Alaska magnetic trough is a discrete geophysical feature that indicates the presence of nonmagnetic rocks that make up a large fraction of the crust. The trough does not have a uniform in character in southern Alaska, but instead has distinct eastern and western portions on either side of a central gap.

· The western portion of the southern Alaska magnetic trough is a very large (70-140 by 550 km) area of nonmagnetic source rocks that primarily coincides at the surface with Alaska Range flyschlike sedimentary rocks (including the Jurassic to Cretaceous Kahiltna flysch).

· Kahiltna flysch in the western portion of the southern Alaska magnetic trough currently rests on a significantly thinner continental basement than exists to the north or south of the trough region.

· Discontinuities and internal variations of the southern Alaska magnetic trough may be related to (1) displacement on the Denali fault, (2) some deep-seated magmatic bodies, and (3) variations in the basement beneath the non-magnetic source rocks.

References

Beaudoin, B.C., Fuis, G.S., Lutter, W.J., Mooney, W.D., and Moore, T.E., 1994, Crustal velocity structure of the northern Yukon-Tanana upland, central Alaska: Results from TACT refraction/wide-angle reflection data: Geological Society of America Bulletin, v. 106, p. 981-1001.

Beikman, H.M., Holloway, C.D., and MacKevett, E.M., Jr., 1977a, Generalized geologic map of the western part of sourthern Alaska: USGS Open-file report 77-169-F, scale 1:1,000,000.

Beikman, H.M., Holloway, C.D., and MacKevett, E.M., Jr., 1977b, Generalized geologic map of the eastern part of southern Alaska, USGS Open-file report 77-169-B, scale 1:1,000,000.

Fuis, G.S, Ambos, E.L., Mooney, W.D., Christensen, N.I., and Geist, E., 1991, Crustal structure of accreted terranes in southern Alaska, Chugach Mountains and Copper River Basin, from seismic refraction results: Journal of Geophysical Research, v. 96, n. B3, p. 4187-4227.

Fuis, G.S., Murphy, J.M. Lutter, W.J., Moore, T.E., Bird, K.J., and Christensen, N.I., 1997, Deep seismic structure and tectonics of northern Alaska: Crustal-scale duplexing with deformation extending into the upper mantle: Journal of Geophysical Research, v. 102, n. B9, p. 20,873-20,896.

Grantz, A., Moore, T.E., and Roeske, S., 1991, Gulf of Alaska to Arctic Ocean: Centennial Continent/Ocean Transect #15, TRA-A3, The Geological Society of America, 2 sheets.

Wilson, F.J., Dover, J.H, Bradley, D.C., Weber, F.R., Bundzten, T.K., and Haeussler, P.J., 1998, Geologic map of central (interior) Alaska: USGS Open-file report 98-133, 3 sheets, scale 1:500,000, 63 pp.