Basement Geophysical Interpretation of the National Petroleum Reserve Alaska (NPRA), Northern Alaska - Part I, Overview

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INTRODUCTION

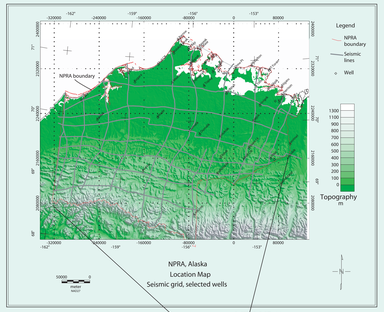
As part of a U.S. Geological Survey project to reassess oil and gas potential for northern Alaska, we are applying gravity and magnetic analysis to the understanding of basement character in the National Petroleum Reserve in Alaska (NPRA). An interpretation of the basement geology is important to developing and evaluating oil and gas plays for deeper parts of the basin. As used here, basement is the portion of the crust bounded at the top by the seismic basement interface and at the bottom by the Moho.

We modeled and removed the expected gravity effect of basin-filling rocks using depth and velocity constraints from seismic interpretation and some density information from drill core measurements. The resultant basement gravity anomaly map shows that basement density increases to the south.

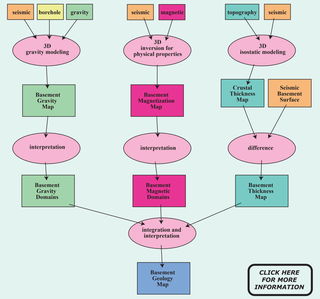
Analysis of the broad, very high-amplitude magnetic anomalies of the North Slope deep magnetic high show that much of southern and southeastern NPRA is underlain by strongly magnetic basement. Unreasonably high predicted basement susceptibilities indicate that portions of these broad magnetic highs arise from magnetic source rocks that must be present above basement within the Ellesmerian portion of the basin.

Basement thickness estimates indicate a thinned zone where the basement is dense and strongly magnetic.

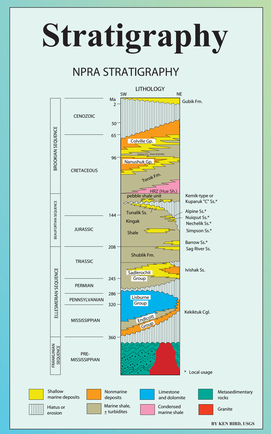
LOCATION MAPS



Project flowchart



Stratigraphy



Gravity domains

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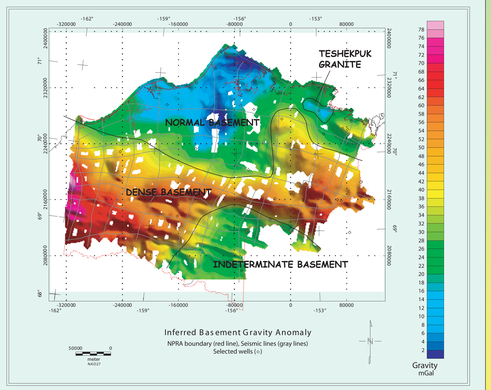

Magnetic domains

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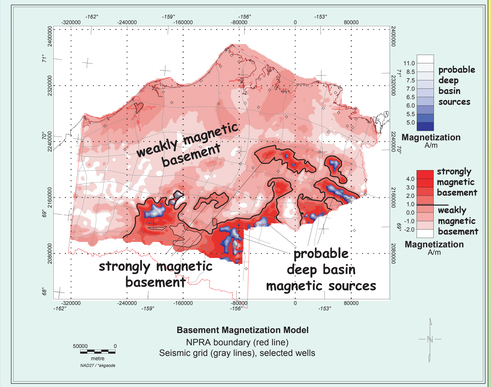
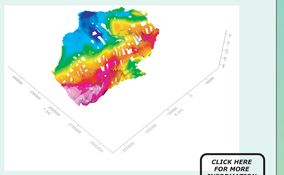


3D Basement Gravity on Seismic Basement Surface



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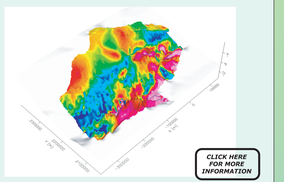
Southeast NPRA scenery

3D Basement Magnetization on Seismic Basement Surface



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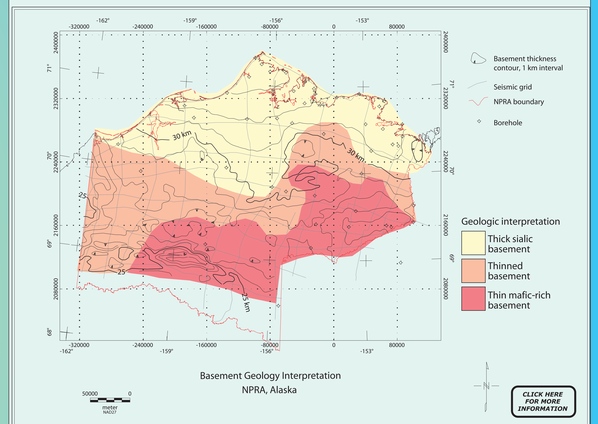
Ground Magnetic Profile in Southeast NPRA

Geological interpretation map



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Conclusions/References

From north to south the total thickness of the basement portion of the crust decreases from 32 km to 26 km, a 20% decrease. This zone of thinning roughly coincides with a predicted increase in basement density from analysis of gravity data and a transition from weakly to strongly magnetized rocks. The thinned, dense, and strongly magnetic basement may indicate a region that has undergone more than 20% extension and experienced extensive mafic magmatism. Because the denser and more magnetic rocks spatially overlap the thickest Ellesmerian sections and because some magnetic source bodies must be locally present within the Ellesmerian section, the postulated mafic magmatism is at least in part contemporaneous with Ellesmerian deposition. Possible outcrop analogs for this mafic magnatism are exposed in the Noatak region of the western Brooks Range (Saltus and others, 2001).

Gryc, George, 1985, The National Petroleum Reserve in Alaska - Earth-Science Considerations: U.S. Geological Survey Professional Paper 1240-C, 94 pp.

Gryc, George (ed.), 1988, Geology and Exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U.S. Geological Survey Professional Paper 1399, 940 pp.

Saltus, R.W., Hudson, T.L., Karl, S.M., and Morin, R.L., 2001, Rooted Brooks Range ophiolite: Implications for Cordilleran terranes: Geology, v. 29, n. 12, p. 1151-1154.

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http://geology.cr.usgs.gov/pub/open-file-reports/ofr-01-0476/

Basement Geophysical Interpretation of the National Petroleum Reserve Alaska (NPRA), Northern Alaska – supplementary text

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TEXT TO ACCOMPANY BOXES ON POSTER PANEL 1 – Part I, Overview

Project flowchart

This box contains a pictorial representation of geophysical modeling and interpretation done for this project. The colored rectangles represent things: data and maps. The pink ovals represent processes: modeling and interpretation. The rectangles are color coded by data type: seismic information is orange, borehole data is yellow, gravity is light green, magnetics is magenta, and topography is blue-green. The first column depicts the three-dimensional gravity modeling described in more detail on poster panel 2. The second column depicts the three-dimensional magnetic interpretation that is described on poster panel 3. The third column depicts the construction of the basement thickness map on poster panel 2. Each of the three columns culminates in an intermediate product (the maps of basement gravity domains, basement magnetic domains, and basement thickness) that is then integrated into the geological interpretation map.

Gravity domains

This map shows interpreted basement gravity values and three general gravity domains in NPRA. The basement gravity values are the result of subtracting the predicted sedimentary basin gravity effect from the isostatic residual gravity anomaly as described on poster panel 2. The northern domain encompasses a region with low to neutral gravity values – this is a region of normal, sialic density. The region labeled “dense basement” is a domain with high regional density – possibly indicating the presence of much more mafic material than in the northern region. A third domain, labeled “indeterminate basement”, in the southern portion of the map, appears to have intermediate gravity values relative to the other two domains, but we consider this domain to be poorly resolved due to uncertainties in seismic interpretations beneath the overthrusted region.

Magnetic domains

This map shows interpreted basement magnetic domains that result from the interpretation described on poster panel 3. For the most part, the predicted magnetizations of basement rocks are reasonable and sufficient to explain the observed magnetic anomalies. However, in some regions (shown in blue colors on the map), the predicted basement magnetization values are large relative to the typical range of crustal magnetization values. In these regions we postulate instead that rocks with somewhat lower intensity magnetization occur above basement within the deeper parts of the

overlying sedimentary basin. We postulate that these intra-basin sources are mafic rocks that may be related to magnetic sources in the basement beneath those locations.

3D Basement Gravity on Seismic Basement Surface

This figure is a perspective view of the basement gravity anomaly (colors) draped on the topographic relief of the seismically determined basement surface. The view is from the southwest. Note the correlation between depth to basement and basement gravity: the lowest basement gravity anomaly values occur in the northern part of the map where basement is relatively shallow whereas the basement gravity highs occur where basement is deeper in the south and southeast portions of the area.

3D Basement Magnetization on Seismic Basement Surface

This figure is a perspective view of the inferred basement magnetization (colors) draped on the topographic relief of the seismically determined basement surface. The view is from the southwest. Note the correlation between the regions of highest inferred magnetization and the deepest portions of the basin.

Geologic interpretation map

This map summarizes our preliminary geological interpretation based on the geophysical modeling and analysis. The yellow, peach, and salmon colored regions indicate three basement domains. The black contour lines show basement thickness. The northern domain is a region of low-to-neutral basement gravity, shallow depth-to-basement, thick basement, and low-to-moderate inferred basement magnetization. The central domain is a region of high basement gravity, greater depth-to-basement, thinned basement, and moderate basement magnetization (including regions where we postulate magnetic sources that are shallower than basement). The southern domain is a region of indeterminate basement gravity (because of uncertainties in seismic interpretation), greatest depth-to-basement, thinnest basement, and high basement magnetization.

Conclusions/References – Poster panel 1

The poster text emphasizes our preferred hypothesis for the interpretation of the geophysical anomalies, but other geological interpretations are possible. For example, the observed geophysical variations in the basement could reflect pre-Ellesmerian basement elements. However, we are struck by the spatial overlap of dense and magnetic basement with area of thickest Ellesmerian deposition (Bird, 1988) and increased basement normal faulting (based on the Tetra Tech seismic mapping). These relationships combined with the need for some of the magnetic source rocks to be within the Ellesmerian section (see poster panel III), creates strong ties between development of dense and magnetic basement character to at least some part of the Ellesmerian history on the North Slope. Information that could help further refine basement interpretations includes (1) better geologic and geophysical mapping and age dating of exposed mafic and ultramafic rocks in northern Alaska, (2) several deep boreholes to directly sample

basement in the NPRA, (3) higher resolution seismic data and more detailed 3D modeling in the southern portion of the study area.

ACKNOWLEDGMENTS

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