Mapping the subsurface geometry of the Moyie Anticline, southeastern British Columbia: Implications for mineral exploration

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Summary

Application of seismic reflection profiling methods to analyzing the regional and detailed structural and stratigraphic features of the Moyie anticline in the Purcell anticlinorium of southeastern British Columbia has provided new perspectives on subsurface variations that may assist in exploration for sedimentary-hosted mineral deposits. The Moyie anticline is the southernmost of a series of north-plunging nested anticlines and is cored by folded Mesoproterozoic Aldridge Formation turbidites of the Belt-Purcell Supergroup that have been intruded by syndepositional mafic Moyie Sills. Aldridge Formation rocks have been productive sources for Pb-Ag-Zn deposits. Mapping of key stratigraphic markers, delineated by extensive, reflective, and correlatable sill horizons, allows identification of time thickness variations that are likely associated with stratigraphic thickness changes that may assist in future exploration efforts.

Introduction

The seismic data were originally recorded for petroleum industry exploration, but are located in a region of extensive sedimentary-hosted mineral deposits. As a result, and because the data provide clear images of sedimentary and igneous features, the study addresses a potential tool for mineral exploration. These results were derived from work that originally focused on the crustal structure of the Moyie Anticline where some of the deepest stratigraphic levels of the Mesoproterozoic Purcell Group strata are exposed.

Regional Stratigraphy

The Belt-Purcell Supergroup was deposited on Precambrian basement rocks and is unconformably overlain by the Windermere Group, Cambrian clastic or carbonate rocks (Höy, 1993). The oldest exposed rocks are the Aldridge Formation which consists of deep-water shales, argillites and turbidites which have been intruded by gabbroic sills (Höy, 1993). The Moyie sills are mafic sills which are concentrated within the Lower and Middle Aldridge Formation (Höy, 1993). Hamilton et al. (1983) suggest that the Moyie sills make up approximately a quarter of the thickness of the Lower Aldridge and are genetically, as well as temporally, related to the post-ore alteration fluids in the vicinity of the Sullivan deposit near Kimberly. Rapid precipitation of sulfides from ascending, metal-bearing fluids flanking locally focused seafloor vents formed the Sullivan deposit as a relatively unmetamorphosed, proximal, clastic-hosted deposit which lies conformably at the top of the lower Aldridge (Hamilton et al. 1983). The Lower Aldridge – Middle Aldridge transition is a key stratigraphic interval for mineral exploration.

Regional Structure

The Purcell anticlinorium was deformed in the Jurassic, when a series of contractional faults caused uplift and repetition of the strata into a series of north-plunging, nested anticlines, the structurally lowest of which is the Moyie anticline (Figure 1). The subsurface structure of the Moyie anticline that is visible on the reflection profiles is outlined by a thick succession of Mesoproterozoic Moyie sills that were intruded into the Mesoproterozoic Aldridge Formation (e.g. Cook and Jones, 1995).

Database and Methods

More than 1000 km of seismic reflection data were recorded by Duncan Energy for petroleum exploration (Figure 1) in and around the Purcell Anticlinorium. Previous studies have combined seismic lines into regional profiles that focus on crustal and upper mantle structure; however, some lines that had not been processed previously are available for more detailed work. Such data are valuable in developing three-dimensional geometry of key structures. In addition, little effort had been previously directed to enhancing the seismic images of the near-surface. As a component of the research described here is to address potential mineral deposits, applications of techniques to improve near-surface resolution have been applied in an effort to delineate structures or trends that may be important in exploring for such deposits in the vicinity of the Moyie anticline region. While the fundamental geometry of the regional structures did not change, the reprocessing was successful in producing substantial improvement in some key areas. A time-migration was applied to these newly processed sections using a similar algorithm to that of the regional studies. Some lines required padding (adding blank traces) to allow steeply-dipping features to be moved up-dip into their proper locations and geometries.

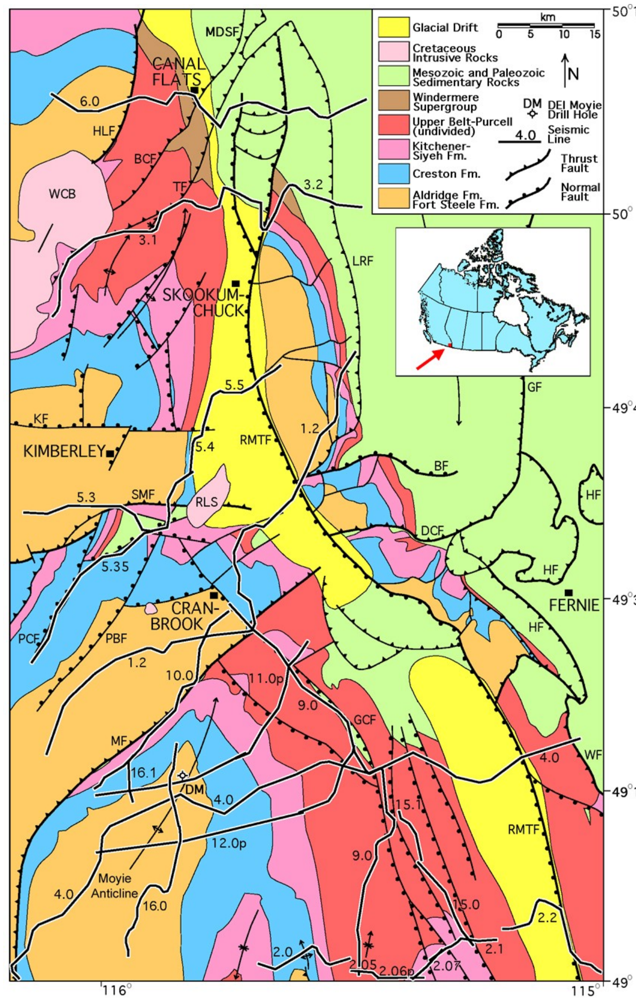

Figure 1: Geologic map of southeastern British Columbia with the locations of the majority of the seismic profiles recorded by Duncan Energy and Duncan Moyie #1 drill hole (DM; modified from van der Velden and Cook, 1996). Boxed area shows the location of this study. Abbreviations used are: BCF, Buhl Creek fault, BF, Boulder fault, DCF, Dibble Creek fault, DM, DEI Moyie#1 drill hole, GCF, Gold Creek fault, GF, Gypsum fault, HF, Hosmer fault, HLF, Hall Lake fault, KF, Kimberley fault, LRF, Lussier River fault, MA, Moyie anticline, MDSF, Mount DeSmet fault, MF, Moyie fault, PBF, Palmer Bar fault, PCA, Porcupine Creek anticlinorium, PCF, Perry Creek fault, RLS, Reade Lake stock, RMBD, Rocky Mountain basal detachment, RMT, Rocky Mountain trench, RMTF, Rocky Mountain trench fault, SMF, Saint Mary fault, TF, Torrent fault, WCB, White Creek batholith, WF, Wigwam fault, WMF, Wigwam-MacDonald fault (combined).

Observations

The regional processed versions of these lines are dominated by two key reflection patterns: a narrow zone of west-dipping reflections between 4.0 and 8.0 s associated with the autochthonous basement, and a prominent zone of arcuate to east-dipping reflections between 0.0 and 3.0 s that are known to be Moyie sills intruded into the Aldridge Formation (Cook and Jones, 1995). The DEI Moyie #1 drill hole was drilled to a depth of 3.477 km in 1987 (Figure 1) by Duncan Energy and provides direct ties between the seismic reflections and the stratigraphy.

Seismic Interpretation

The dominant antiformal structure of the Moyie Anticline is outlined by the Moyie sill reflections, and is confined to the region above the basement. While the new results affirm the regional structures observed previously (Cook and van der Velden, 1995; van der Velden and Cook, 1996), the added detail provides enhanced resolution with resulting potential applications for detailed mapping and mineral exploration.

Description of Key Features

The seismic profiles above NBR are dominated by a broad arcuate zone of dipping reflections in the upper crust (0.0-3.0s) that are a result of the large impedance contrast between the turbiditic Aldridge Formation and gabbroic Moyie Sills (Cook and Jones, 1995). These reflections are divisible into two prominent zones: 1) a narrow sill reflection (called the Middle Aldridge marker) from within the Middle Aldridge Formation, and 2) a thick package of sill reflections from within the Lower Aldridge Formation. Accordingly, these sill reflections straddle the Middle Aldridge – Lower Aldridge transition and, assuming they are more or less parallel to stratigraphic layering, provide an opportunity to map stratigraphic thickness changes near this transition. Such thickness changes may be associated with enhanced mineralization as at the Sullivan deposit (Lydon, 2000).

Interpretations

Because the focus is the three-dimensional structure of the Moyie anticline, and particularly the relatively shallow regions of the structure, and because there are both along and across-strike variations observed on the 2-D lines, maps of key horizons were constructed. Four horizons were picked on the reflection seismic sections using Kingdom Suite interpretation software. They are: 1) the Middle Aldridge Marker, 2) the top of the heavily intruded package in the Lower Aldridge, 3) the base of the reflective layer in the Lower Aldridge, and, 4) the near-basement reflections. After correlating key horizons from line to line, travel times of each horizon are mapped along the lines. These horizons highlight the structure of the anticline shown in the pseudo-grid of seismic sections. Gridding of each the picked horizons provided a series of horizon maps.

An isochron map was created by subtracting the Middle Aldridge marker grid from the top of the Lower Aldridge sill grid. The result (Figure 2) provides a map of the isochronal thickness between these two key markers and may, assuming local velocity variations are small, delineate geological (stratigraphic) thickness variations of the Middle Aldridge – Lower Aldridge transition in this area.

Discussion

The time-structure and interval maps provide a new opportunity to view detailed structural and stratigraphic changes in the upper crust of the Moyie anticline. Although the regional interpretation of the fundamental structure of the Moyie Anticline has not changed substantially, the mapping is capable of adding detail. The isochron map of the Middle Aldridge – Lower Aldridge transition as delineated by the sill refelctions shows substantial thickening (more than 0.5 s, or about 1 km for a velocity of 5.0 km/s) in the centre of the anticline along a N-NW trend (Figure 1).

Conclusions

Mapping of key mafic sill horizons in the Middle and Lower Aldridge formations of the Moyie anticline in southeastern British Columbia has led to the identification of thickness variations that may be significant in exploration for stratigraphically controlled mineral deposits. Specifically, if we assume that the Middle Aldridge marker sill and the top of the Lower Aldridge sill horizon are localized within stratigraphic units, then they provide stratigraphic markers that can be used to seismic time thickness variations that are likely associated with stratigraphich thickness variations. This approach may provide a new tool for mapping the regional extent of such variations in the subsurface of the Purcell anticlinorium and perhaps elsewhere.

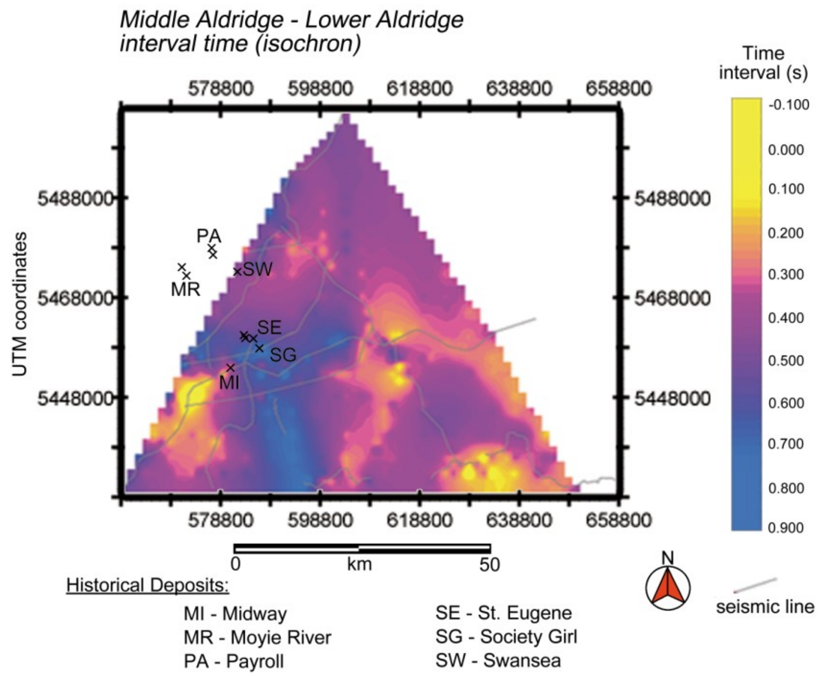

Figure 2: Isochron map of Middle to Lower Aldridge transition zone as delineated by the MAMa to MS (MAMa-MS) reflections with historic lead-zinc mines labeled. Of particular significance may be a NW-SE striking thick zone (trough?) in the western portion of the map. These show a spatial correlation with the mineralization seen at the north end of Moyie Lake.

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