Structural control of hydrothermal dolomitization in the Keg River and Slave Point Formations, Sierra area, NE British Columbia, and analogies with the Ghawar Field, Saudi Arabia

John W. Peirce, GEDCO, Calgary; Graham Davies, Graham Davies Geol. Cons., Calgary; Sergeui Goussev, Lisa Griffith, John Rhodes , GEDCO, Calgary

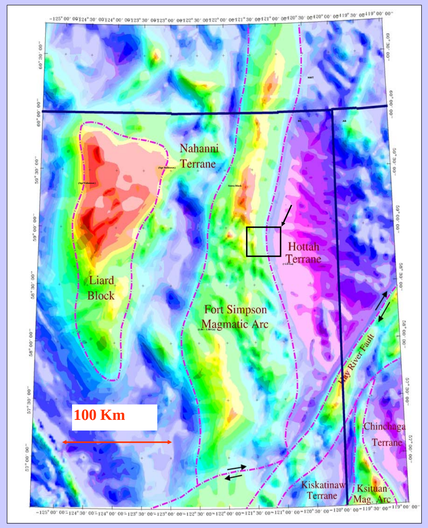
Summary

We have used a combination of detailed core description and interpretation of High Resolution AeroMagnetic (HRAM) data to suggest that the hydrothermal dolomitization occurring in the Middle Devonian Keg River and Slave Point Formations in the greater Sierra area is controlled by Riedel shears in a large scale, left lateral wrench fault system. We note that a similar model has been proposed for the hydrothermal dolomitization in Jurassic Arab D Formation in the Ghawar Field in Saudi Arabia.

There is no core display to accompany this poster.

Basement Terrane Interpretation

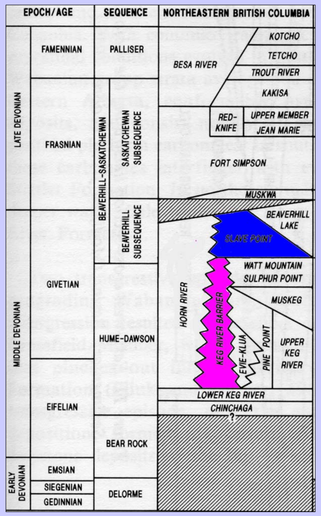
1



Location of study area in NE British Columbia, shown on an image of the total magnetic field with terrane interpretation shown in dashed lines. The study area straddles the boundary between the Hottah and Fort Simpson Terranes.

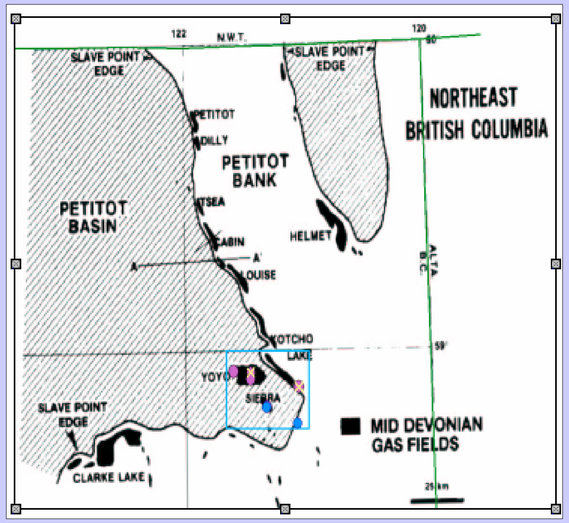
The Fort Simpson Terrane magnetic high is interpreted to represent a pre-collisional magmatic arc (Fort Simpson Arc) accreted onto the eastern margin of the Nahanni Terrane by a west dipping subduction zone. The Hottah Terrane is cut by a swarm of Proterozoic dikes striking to the northwest. These dikes pre-date collison of the Hottah and Ft. Simpson Terranes during the Wopmay Orogeny (ca 1.85 Ga).
Reactivation of these structures during the Devonian may have played a role in localizing both the platform margin and reef development, and providing conduits for the flow of fluids responsible for limestone leaching and dolomitization.

2



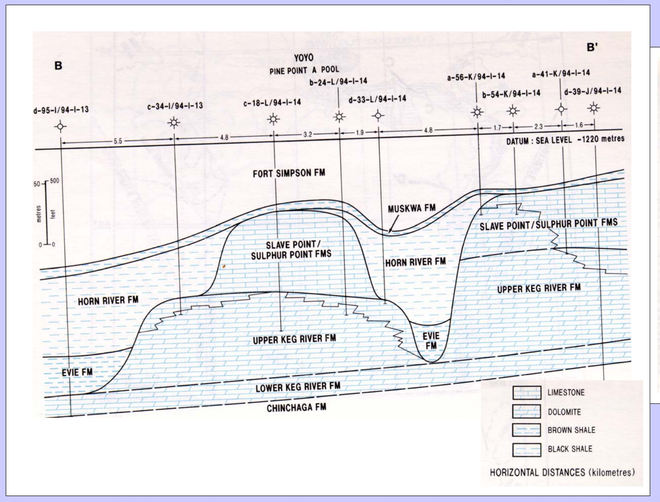
Stratigraphic column for NE British Columbia showing Keg River Fm. in magenta and Slave Point Fm. in blue (after Reinson et al., 1993).

3

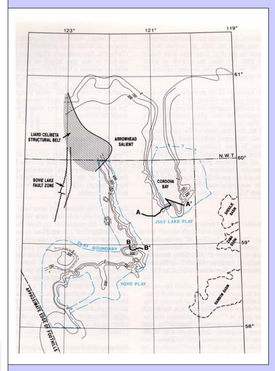


The study area is within a region that contains a number of significant gas fields reservoired within an extensive mid-Devonian reef system. Here we see the Slave Point edge and some of the major producing fields. For this study, 7 wells (20 cores) from the Yoyo and Sierra pools were described. Note the en echelon pattern to the western edge of the Petitot Bank. (Adapted from Phipps, 1989.)

4



The patterns of dolomitization are easily recognizable in this cross section of the Yoyo Reef and the adjacent bank edge. (Reinson et al., 1993) Note that the dolomitization extends higher in the section on the bank edge than in the isolated reef.
The absence of hydrothermal dolomite in the Slave Point buildups outboard of the regional shelf margin (e.g. c-78-C) is consistent with their isolated and insulated stratigraphic position in a blanket of shale, even though the location occurs on a mapped strike slip fault. Shales lack both the rigidity to fracture, and the permeability to transmit fluids.



Host Strata/Age: Keg River and Slave Point Formations
Type Area: Northeast British Columbia, Canada
Present Depth: 1950 to 2225 m
Representative HC Pools/Mineral Deposits: Yoyo, Sierra, Kotcho Lake Fields
Investigative Methods: High Resolution AeroMagnetic (HRAM) interpretation, core description

Interpretation of Key Conditions of Dolomitization

Substrate: amphiporid and dendroid stromatoporoid floatstone and grainstone/packstone
Burial Depth: probably less than 500 m
Temperature: estimated at 120º to 160ºC
Timing: Late Devonian to Early Mississippian
Fluid Type: hydrothermal brines
Fluid Transport: faults and underlying aquifer (?)

5

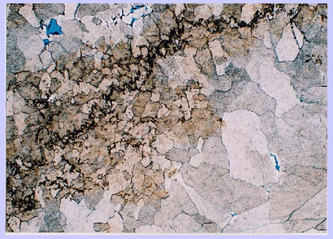
b

b-29-I , 94-I-13: 2239m Keg River

c

b-98-E , 94-I-13: 68m Keg River

d



b-29-I, 94-I-13: 2237m Keg River

Coarse crystalline void-filling saddle dolomite crystals (upper left, lower right) extending outward from brown, inclusion-rich replacive saddle dolomite along a stylolite, with minor intercrystalline porosity (blue epoxy).

a

d-57-H, 94-I-13: 1974m Slave Point

The common occurrence of zebra fabrics with integral inclined shear micro-fractures in at least 9 of the Keg River cores is of even greater significance than the presence of saddle dolomite (b-29-I, fig. 5d). We believe that zebra fabrics are the product of hydro-fracturing under shear stress, and are formed proximal to faults (particularly extensional and/or strike slip types), e.g. d-57-H, fig. 5a. The shear micro-fractures compartmentalize the zebra fabric; that is, hydro-fracturing and ‘expansion’ of the zebra fabric is bounded by inclined shear micro-fractures, e.g. b-29-I, fig. 5b. In Yoyo b-98-E, fig. 5c, the upward increase through a 40 m interval in both the total volume of void-filling coarse saddle dolomite, as well as the frequency and size (thickness) of zebra fracture sets is consistent with an upward decrease in confining stress (pressure release) at the time of zebra hydro-fracturing.

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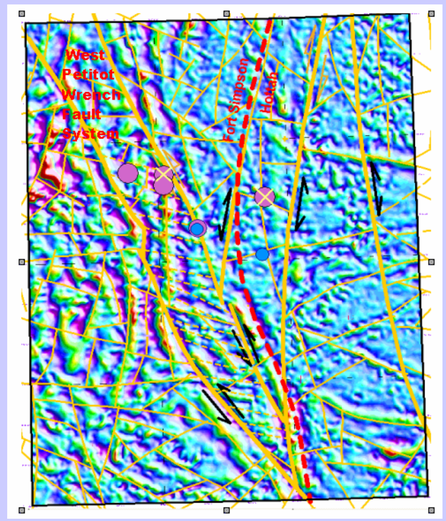
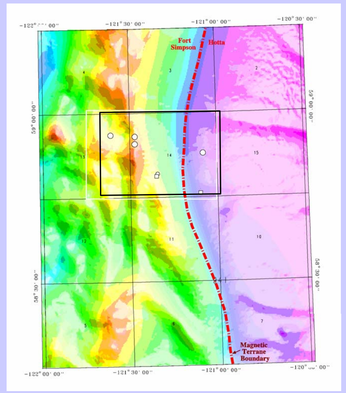
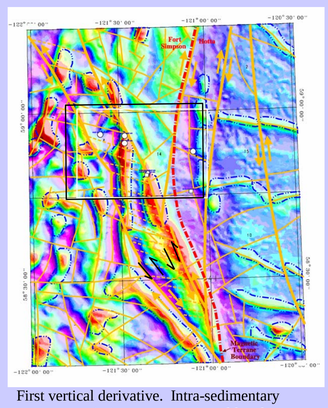


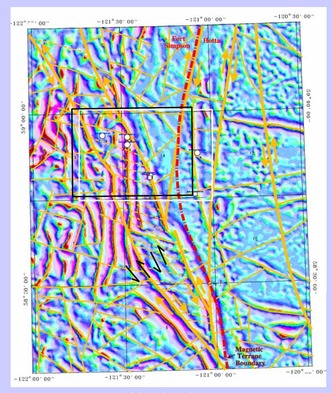
7 a-e



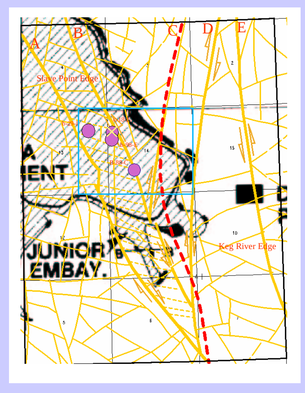
Total magnetic field (reduced to pole)



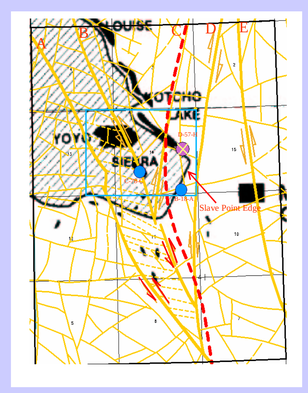
First vertical derivative. Intra-sedimentary structure grain interpretation in gold and intra-basement intrusions outlined in blue.



1.2 – 4.8 km band pass



Interpreted intra-sedimentary structure grain and Key River edge and wells



Interpreted intra-sedimentary structure grain and Slave Point edge and wells

Our understanding of the Proterozoic construction of the Western Canada Sedimentary Basin (WCSB) is largely dependent upon our interpretation of aeromagnetic data. In the study area, we would like to highlight two important features identified by aeromagnetic data: a terrane boundary partially coincident with the platform edge, and a wrench-fault system trending through the isolated Sierra and Yoyo build-ups. Published interpretations of the boundaries (GEDCO updated version after Pilkington et al., 1994) place the Sierra Field just west of the boundary between the Fort Simpson and Hottah Terranes.

Figures 6 and 7c show the 1.2 to 4.8 kilometer band-pass filter of the total magnetic field grid. This filter was designed to suppress the long wavelength component of the data (the broad highs and lows associated with the interpreted terrane blocks). The filter also suppresses the very short wavelength component, associated with near surface features, such as river channels, residual culture and outcropping geology. The resultant grid emphasizes edges of the terrane blocks, and the fault fabric of the lower sedimentary section and Precambrian basement. Two northwesterly magnetic trends, which pass through the Sierra study area, are interpreted with thick gold lines as strike slip faults. Three other strike slip faults, oriented north-south, were interpreted in the eastern part of the study from breaks and lateral offsets of magnetic trends.

Subtle west-northwesterly trends, interpreted with thin dashed lines, also become apparent using this filter. These were interpreted as Riedel shears within the West Petitot Wrench Fault System.

References

Cantrell, D.L., et al, in press 2004. Title unknown. GeoArabia, v.9, no.2, 1-26.

Phipps, G.G., 1989. Exploring for dolomitized Slave Point carbonates in northeastern British Columbia. Geophysics, v. 54, p. 806-814 .

Pilkington, M. Wiles, W. F., Ross, G. M., and Roest, W. R., 2000. Potential field signatures of buried Precambrian Basin. Can. Jour. Earth Sci., 37, 1453-1471.

Reinson, G., Lee, P.J., Warters, W., Osadetz, K.G., Bell, L.L., Price, P.A., Trollope, F., Campbell, R.I., and Barclay, J.E., 1993. Devonian gas resources of the Western Canada Sedimentary Basin, Part I: Geological play analysis and resource assessment. Geol. Surv. Can. Bull. 452, p. 36-68.

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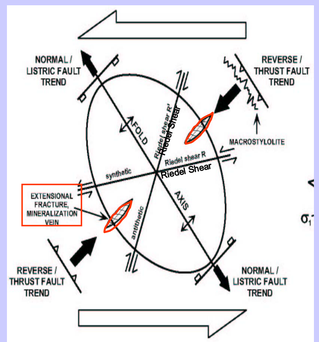
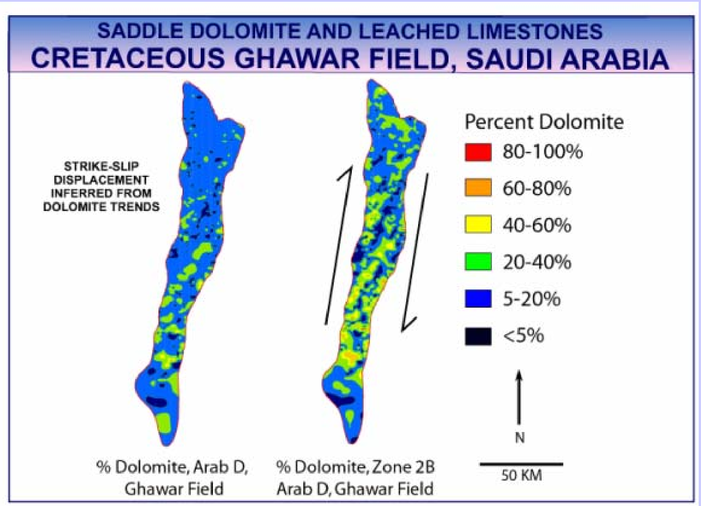


9

The Riedel shears in the WNW trends were formed between two major strike slip faults of the West Petitot Wrench Fault System. These extensional fractures are the likely local conduits for hydrothermal fluids. Due to the basis of the interpreted Riedel shears, the West Petitot Wrench Fault System has a left lateral motion. The photographic example shows Riedel shears from an outcrop of the Devonian Old Red Beds in Scotland.

10



The primary reservoir of the Ghawar Field (the world's largest oil field), in Saudi Arabia, is the Jurassic Arab 'D' Formation. Using the extensive well control in the field, Cantrell et al. (in press 2004) have mapped the percentage of dolomite distribution in the field. Although they interpret three different kinds of dolomite, it is the occurrence of baroque (hydrothermal) dolomite, distributed vertically along fractures, that controls the variation in the percentage of the dolomite in the reservoir. They interpret this striking pattern of dolomite distribution as being structurally controlled by Riedel shears in a right lateral wrench system. The wrench system is presumably related to stresses arising from the collision of the Arabia with Eurasia.

Conclusion

Core evidence indicates extensive dolomitization and fracturing in Keg River facies with low initial permeability in the Sierra area. Aeromagnetic interpretation identifies the location and geometry of 5 major strike slip faults within the study area. Both the Sierra and Yoyo reefs occur between two of these faults; Riedel shears have also been identified between these faults 'A' and 'B'. The interpretation of Riedel shears on aeromagnetic interpretation is a powerful exploration tool. Large-scale strike-slip faults help to establish a play area, but the presence of Riedels in conjunction with a carbonate build-up and low permeability facies will identify prospects. The probability of finding excellent reservoir in the vicinity of Riedel shears is very high, due to localized flow of thermobaric dolomitizing fluids.

The Slave Point Fm has been dolomitized only in the paleo-shelfal position. Experience in other parts of the basin also suggests that Slave Point build-ups within the shale basin do not make good exploration candidates.

Acknowledgements

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