Paleomagnetic dating of diagenetic events in Paleozoic carbonate reservoirs of the Western Canada Sedimentary Basin

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ABSTRACT

Paragenetic sequences for sedimentary rocks provide information on their geologic histories by establishing the order of diagenetic events such as compaction, mineral replacement, mineralization, fracturing and porosity evolution. Thus, a paragenetic sequence can be used to determine the age of a specific diagenetic event relative to other events. It is much more difficult to get an absolute age for that event. Direct radiometric dating of a specific mineral in the sequence will provide an absolute age date for the mineral, and the minimum and maximum age for the diagenetic events preceding and following, respectively. However, only a few studies have used radiometric techniques, either due to limitations of the techniques themselves or to a scarcity of datable minerals. Most studies of this type have been carried out on illite, calcite, glauconite, potassium feldspar and sphalerite, using Rb-Sr, U-Pb, 40Ar/39Ar, or Th-U-Pb techniques (e.g. Hearn et al. 1987; Smith et al. 1991; Daniels et al. 1991; Brannon et al. 1992; Brannon et al., 1996).

More typically, only constraints can be placed on the absolute timing of the diagenetic events. This can be done through a knowledge of the physical, chemical or thermal conditions that are needed for, or favour, the formation of specific minerals found in the sequence. Also it can be done through the use of techniques such as stable isotope and fluid inclusion analysis that provide information on the composition and temperature of the fluid precipitating or replacing minerals in the sequence (e.g. Al-Aasm et al., 2000; Lonnee and Al-Aasm, 2000).

Paleomagnetism provides another method for directly dating diagenetic events (Elmore et al., 1985), providing that the paleomagnetic signal can be tied to a specific event. The difficulty lies in isolating a specific event that has produced a given mineral or a coeval mineral to it that can be analyzed paleomagnetically. Commonly, the complex paragenetic sequences typical of many carbonates have key events that are represented mineralogically by a small fraction of the total rock volume. Paleomagnetic specimens average 10 cm^3 in volume and thus may be averaging the paleomagnetic signal of several events. Previous work has used paleomagnetic techniques to date large-scale mineralization events such as

the formation of Mississippi Valley-type deposits (Beales et al., 1974; Bachadste et al., 1987; Pan et al., 1990; Symons et al., 1996). Paleomagnetic techniques provide information that can be used for other purposes such as the several methods of core orientation (Cioppa et al., 2000a) or dating of hydrocarbon generation (Cioppa and Symons, 2000).

Recent studies in the Western Canada Sedimentary Basin (WCSB) have focussed on complementary paleomagnetic, petrologic, and geochemical analyses of Paleozoic hydrocarbon reservoirs, and more specifically, the dolomitic phases therein. A typical study involved:

1) standard paleomagnetic and rock magnetic techniques to determine the age of magnetization components, magnetic mineralogy and granulometry;
2) standard petrographic analysis, including light microscopy, cathodoluminescence and fluorescence studies, to determine the depositional facies and paragenetic sequence;
3) geochemical analysis, including stable isotope, Sr-isotopes, major, minor, and trace element analysis;
4) fluid inclusion analysis; and,
5) geochemical modelling.

In the Devonian Sulphur Point Formation of the Rainbow South reservoir, petrographic and geochemical analyses have demonstrated the presence of several distinct dolomitization phases formed during diagenesis: dolomicrite, fine-crystalline dolomite, medium-crystalline dolomite, saddle dolomite, and fracture-lining dolomite (Lonnee and Al-Aasm, 2000). Paleomagnetic and rock magnetic analyses have identified distinct magnetic components corresponding to three of the phases: fine-crystalline dolomite, medium-crystalline dolomite and saddle dolomite. We are thus able to directly date these three phases as being Late Jurassic / Early Cretaceous, Late Cretaceous, and Tertiary in age, respectively.

Identification of the depositional facies and corresponding facies-specific diagenetic events has proven to be important in several of the studies. In the Shell Limestone, Anderson Dunvegan, and Rigel Rainbow South (Cioppa et al., 1999, 2001a; 2001b) studies, the paleomagnetic and facies analyses have shown that relatively coarse-grained facies such as packstone and wackestone are more likely to carry a Laramide-age magnetic overprint than fine-grained mudstone or micrite. However, the actual control on the distribution of magnetizations has not yet been determined and, thus, the role that carbonate diagenesis has played in the WCSB is not completely understood. Magnetization distribution may be related to the depositional grain size, porosity, or some subsequent diagenetic event.

Petrographic, geochemical and fluid inclusion analyses for the above studies have demonstrated distinctive differences in fluids precipitating the various dolomites found in the paragenetic sequences of the different reservoirs. Thus, the combination of paleomagnetic, petrographic and geochemical data do provide us with tools to date diagenetic events, and also to identify the specific fluid flow event that precipitated minerals and to examine its spatial distribution.

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