A comparison of shale compositions from the Western Canada Sedimentary Basin and the U.S. Gulf Coast: the importance of depositional composition on shale diagenesis

P. de Caritat *Geological Survey of Norway, P.O. Box 3006-Lade, N-7002 Trondheim, Norway*

J. Bloch *Scealu Modus, 2617 Cutler Ave. N.E., Albuquerque, New Mexico 87106, USA.*

I. Hutcheon *Department of Geology and Geophysics, The University of Calgary, Calgary, Alberta T2N 1N4, Canada*

F.J. Longstaffe *Department of Earth Sciences, The University of Western Ontario, London, Ontario N6A 5B7, Canada*

H.J. Abercrombie *Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary, Alberta T2L 2A7, Canada.*

Introduction

The mineralogical, bulk-rock and clay-fraction geochemical, and clay-fraction O-isotopic compositions of shales from the Western Canada Sedimentary Basin (WCSB) and the U.S. Gulf Coast (USGC) are compared to evaluate the effects of depositional mixing and burial diagenesis on shale composition.

The WCSB shale study

Caritat *et al.*, (1994) collected shale and bentonite core samples from the WCSB along an east-west basinal cross-section within the Cenomanian Belle Fourche Formation (Lower Colorado Group). Sampling targeted a variety of depositional settings (pro-deltaic to hemipelagic), depths (< 300 to > 3000 m) and thermal maturities (T_{max} = 406°–518°C), in order to allow evaluation of the depositional and diagenetic controls on shale composition. The samples were examined petrographically by back-scattered electron microscopy (with an energy-dispersive X-ray detector), and were analyzed by Rock-Eval pyrolysis and X-ray diffraction of whole-rock powders and oriented, < 2 μm and < 0.2 μm size fractions. Bulk-rock and clay-fraction (< 0.2 μm) geochemistry was determined by X-ray fluorescence, total organic carbon and sulphur determinations. O-isotope composition of shale clay-fractions (< 0.2 or < 0.5 μm) was determined by standard techniques, and results are reported in standard δ notation relative to SMOW. The resulting compositional trends of the Belle Fourche Formation shales have been interpreted as reflecting mainly the initial, depositional compositional variation within this unit (Caritat *et al.*, 1994). Only minor diagenetic modification occurred, mainly in the east where bentonite-derived smectite underwent slight 'illitization'.

The USGC shale study

The USGC cutting samples (1300-5600 m) originate from a well (CWRU6) in the Texas coastal plains, where the Oligocene–Miocene Frio and Anahuac Formations were intersected (Hower *et al.*, 1976). The geochemical and mineralogical data presented by Hower *et al.*, (1976), and the O-isotope data presented by Yeh and Savin (1977), were used in these seminal papers to interpret the observed compositional trends as reflecting primarily 'illitization' of deposited smectitic clay material, according to the now prevalent model of mixed-layer illite/smectite (I/S) diagenesis. In the USGC study, detrital compositional variability was not considered as having a significant influence on present-day depth trends of illite content in I/S.

Discussion

Despite the radically contrasting genetic interpretations for the contained I/S, the compositions of WCSB and USGC shales are essentially indistinguishable, in terms of both bulk shale and clay fraction compositions (Fig. 1). This observation implies that similar mineralogical and chemical trends (i.e., from smectitic to illitic

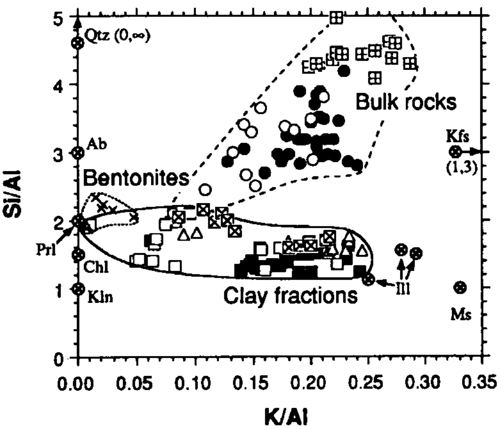

FIG. 1. Si/Al vs. K/Al diagram illustrating the geochemical-mineralogical relationships of the Belle Fourche Formation bulk shales (circles), bentonites (crosses), analyzed clay fractions (triangles) and calculated clay fractions (squares), and of the U.S. Gulf Coast (Hower *et al.*, 1976) bulk shales (squares with plusses) and analyzed clay fractions (squares with crosses). Where open and closed symbols exist, these represent thermally immature ($T_{max} \leqslant 435°C$) and mature ($T_{max} > 435°C$) samples, respectively. Minerals quartz (Qtz), albite (Ab), pyrophyllite (Prl), chlorite (Chl), kaolinite (Kln), three different illites (Ill), muscovite (Ms) and K-feldspar (Kfs) are indicated by crossed circle symbols.

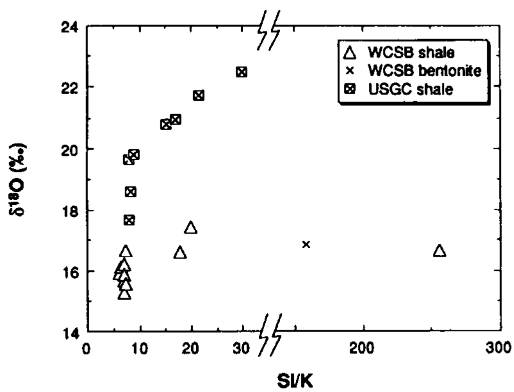

FIG. 2. $\delta^{18}O$ (SMOW) vs. Si/K value for Belle Fourche Formation clay fractions (triangles) and one bentonite (cross) and U.S. Gulf Coast clay fractions (squares with crosses) (isotopic data from Yeh and Savin, 1977; Si/K values derived from data in Hower *et al.*, 1976). Note the large differences in absolute $\delta^{18}O$ values and in $\delta^{18}O$ range between these two populations, and the similarity in shape of both trends with decreasing Si/K value ('illitization'). Si/K of illite ranges from *c.* 4–6. Note also break in scale on abscissa.

I/S) with depth or temperature can result either from inherited depositional compositional inhomogeneities of the sediment, from burial metamorphism of shale, or a combination of both. Therefore, it may not be warranted in all cases to call upon the 'smectite illitization' model to explain such trends. Interestingly, the O-isotopic compositions of the clay fractions from the WCSB and USGC are significantly different (Fig. 2), a fact that reflects genesis under different conditions (temperature, O-isotopic composition of water, etc.).

Conclusions

We conclude that, in shales, the mere observation of the existence of trends going from smectitic to illitic I/S with depth, thermal maturity, or any other variable, does not constitute in itself a viable argument or a *raison d'être* for the commonly cited, if intrinsically abstruse, 'illitization' mechanism and the associated set of reactions. The initial, depositional composition of shales must be carefully considered in any diagenetic investigation, as its influence on present-day compositional trends may mask or mimic those of diagenesis.

References

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