PSThe Application of Chemostratigraphy to Fluvial-Deltaic Sequences: from Example from the Ferron Sandstone Member, South-Central Utah*

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Abstract

The Cretaceous-aged Ferron Sandstone Member (Mancos Shale Formation) comprises a series of fluvial and deltaic sequences deposited as part of the Notom Delta complex, south-central Utah. Although a significant proportion of the deltaic successions are mudstone-dominated, these fine-grained lithologies have received little attention compared to the coarser grained lithologies. In this study, a better understanding of the mudstone lithologies is attempted using whole-rock geochemical data. Specifically, to determine the efficacy of chemostratigraphy to these predominantly pro-delta to shoreface/delta front sequences, and secondly to better understand their relationship to overlying fluvial mudstones within Ferron Sandstone Member.

Chemostratigraphic analysis was carried out on approximately 210 silty-mudstone field samples collected from eight sections and sampled at approximately 6m intervals. Whole-rock inorganic geochemical data were acquired for all samples using inductively coupled plasma - Optical emission spectrometry (ICP-OES) and inductively coupled plasma - mass spectrometry (ICP-MS). By combining these two analytical methods, a total of 50 elements are determined for each sample.

In this study it is demonstrated that within pro-delta to shoreface/delta front sequences of the Ferron Sandstone Member a number of "chemostratigraphic units" can be recognized and correlated between the analysed sections, based on changes in K/Rb, Mg/Al and Ti/Nb ratio values. The geological factors controlling the geochemical variations within each chemostratigraphic unit are thought to be a complex mixture of changing provenance, changing clay mineral species and periodic volcanogenic influences. Additionally, the inorganic geochemical signature of mudstone samples from fluvial sequences shows a significant difference to that seen from mudstone samples analysed from shoreface/delta front sequences, implying that mudstones in the two settings were potentially derived from different provenances.

Comparisons between the resulting chemostratigraphic correlation and detailed sequence stratigraphic correlations show that mudstone-based chemostratigraphy is a potent correlation tool in shoreface/deltaic settings. The methods applied here within the Mancos Shale Formation can be readily applied to fluvial-deltaic sequences of any age, in any basin, including petroleum basins, where outcrop studies cannot be applied.

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Panel 1

ABSTRACT

The Cretaceous-aged Ferron Sandstone Member (Mancos Shale Formation) comprises a series of fluvial and deltaic sequences deposited as part of the Notom Delta complex, south central Utah. Although a significant proportion of the deltaic successions are mudstone-dominated, these fine grained lithologies have received little attention compared to the coarser grained lithologies. In this study, a better understanding of the mudstone lithologies is attempted using whole-rock geochemical data. Specifically, to determine the efficacy of chemostratigraphy to these predominantly pro-delta to shoreface sequences, and secondly to better understand their relationship to overlying fluvial mudstones within Ferron Sandstone Member.

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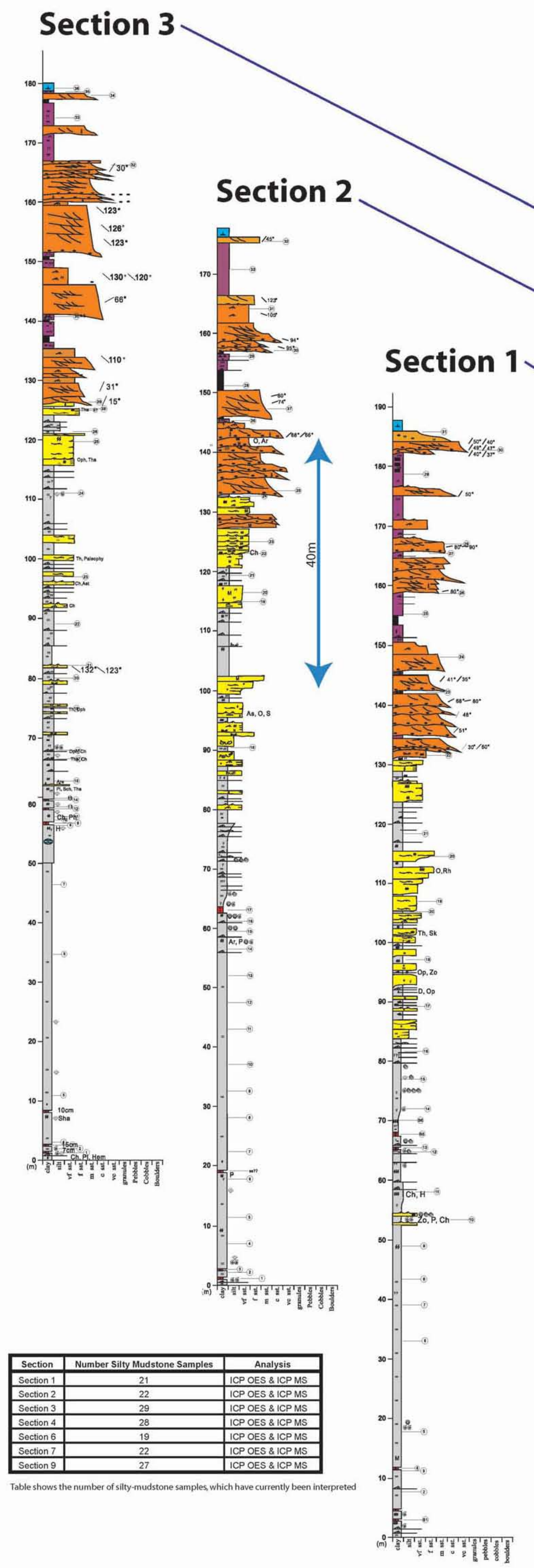
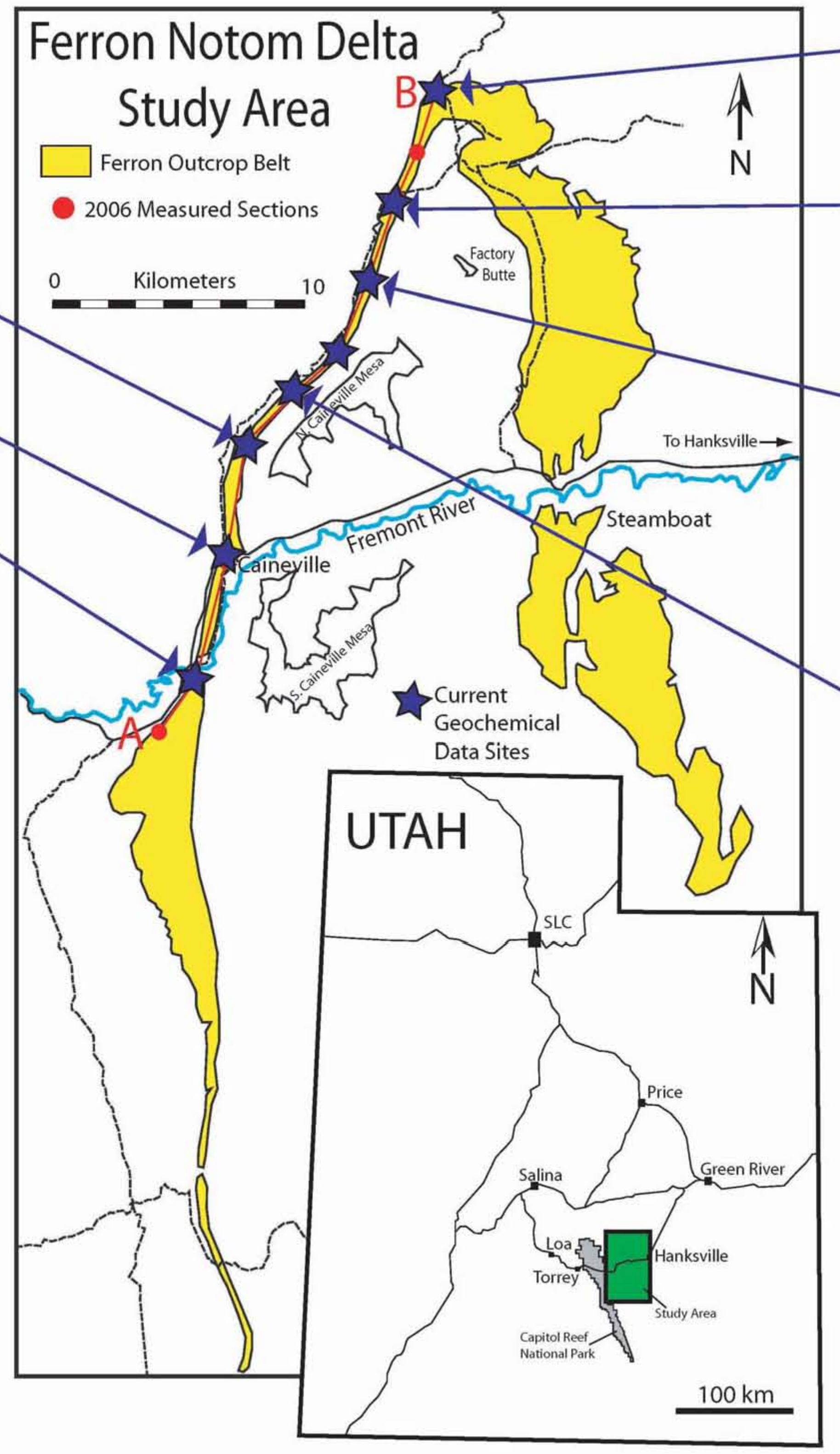
In this study it is demonstrated that within pro-delta to shoreface sequences of the Ferron Sandstone Member a number of "chemostratigraphic units" can be recognized and corrected between the analyzed sections, based on changes in K_2O/Rb, MgO/Al_2O_3 and TiO_2/Nb ratio values. The geological factors controlling the geochemical variations within each chemostratigraphic unit are thought to be a complex mixture of changing provenance, changing clay mineral species and periodic volcanogenic influences. Additionally, the inorganic geochemical signature of mudstone samples from fluvial sequences shows a significant difference to that seen from mudstone samples analyzed from shoreface and pro-delta sequences.

Comparisons between the resulting chemostratigraphic correlation and detailed sequence stratigraphic correlations show that mudstone-based chemostratigraphy is a potent correlation tool in pro-delta settings. The methods applied here to the Mancos Shale Formation can be readily applied to pro-delta settings of any age, in any basin, including petroleum basins, where outcrop studies cannot be applied.



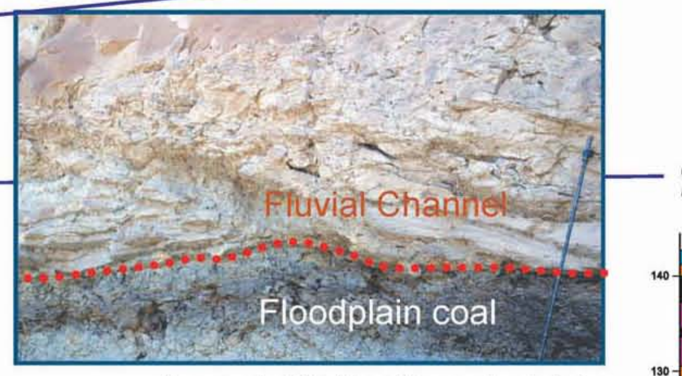
Section	Number Silty Mudstone Samples	Analysis
Section 1	21	ICP OES & ICP MS
Section 2	22	ICP OES & ICP MS
Section 3	29	ICP OES & ICP MS
Section 4	28	ICP OES & ICP MS
Section 6	19	ICP OES & ICP MS
Section 7	22	ICP OES & ICP MS
Section 9	27	ICP OES & ICP MS

Table shows the number of silty-mudstone samples, which have currently been interpreted

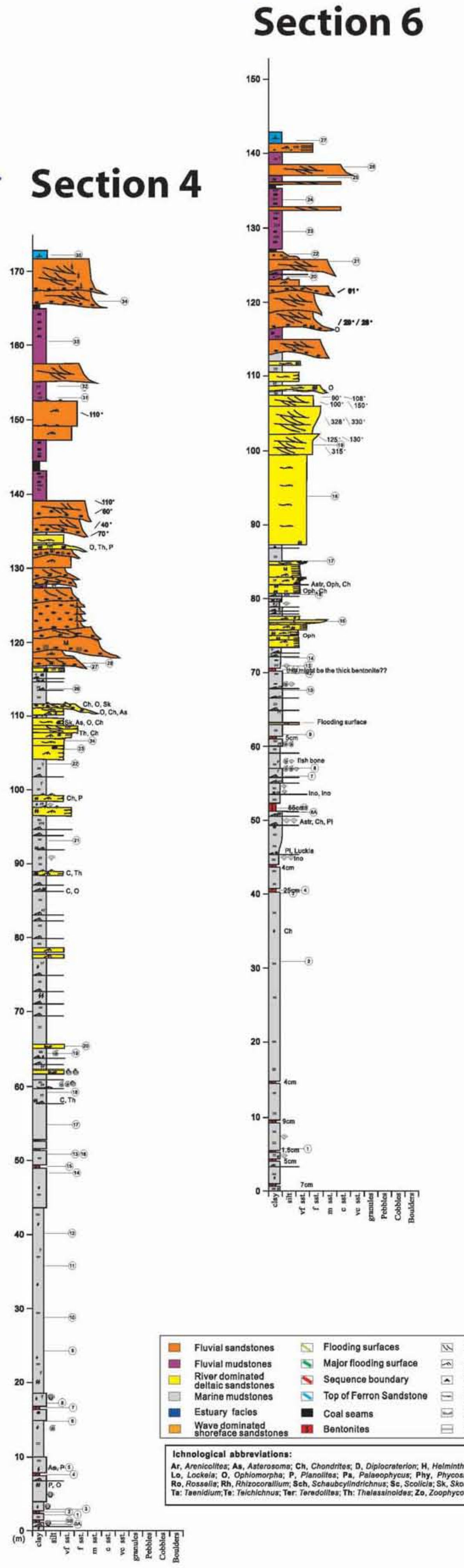


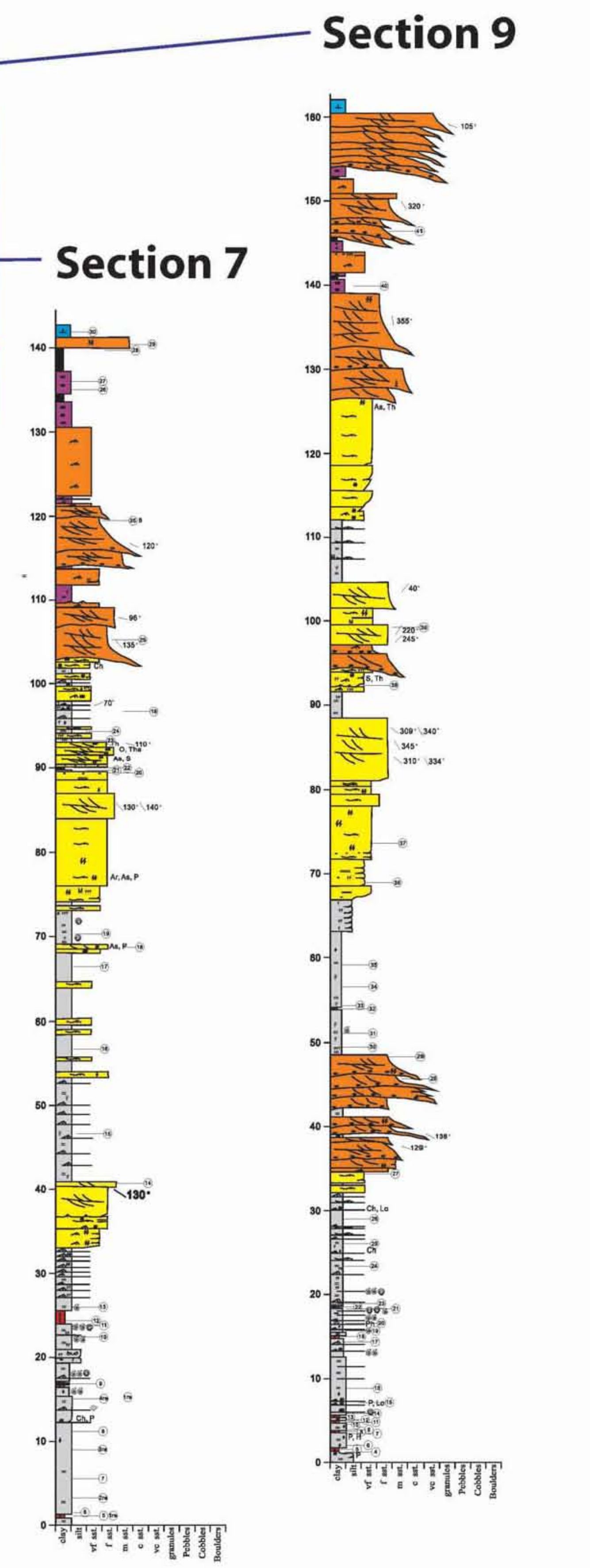
Ferron Sandstone Member in outcrop:

The photograph (above) shows an approximately 40m thick section from "Section 2", where deltaic sequences are overlain by fluvial sandstones. The blue arrow on the photograph, matches to the same interval captured on Section 2

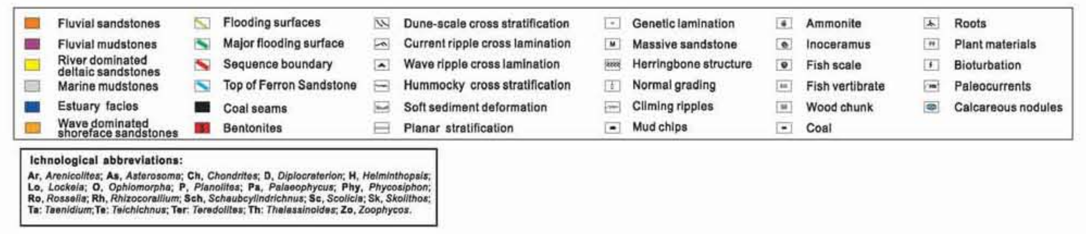


An example of fluvial mudstone and coaly facies





An example of prodelta mudstone facies



PROJECT RATIONALE

Is chemostratigraphy a viable characterization and correlation technique for silty-mudstone facies within fluvio-deltaic sequences?

Extensive studies of the Ferron Sandstone Member (Notom Delta complex) of the Mancos Formation have provided a detailed sequence stratigraphic correlation, with many of the correlations being clearly visible in outcrop. Selected sections within this correlation framework have been sampled for whole-rock geochemical analyses, with the specific aim of determining whether:

- Whole-rock geochemical data can be used to differentiate mudstones deposited in fluvial setting from mudstones deposited in marine shoreface to prodelta settings?
- Changes in sediment provenance, paleoclimate, facies and redox conditions exert influences on the whole-rock geochemistry in deltaic systems? An can these changes be modelled?
- Provenance change in deltaic mudstones be used to determine the amount of fine-grained sediment contributed from fluvial systems verses fine-grained sediment derived from long shore drift processes?

CHEMOSTRATIGRAPHY

Chemostratigraphy is a methodology that involves the use of major and trace element geochemistry for the characterization and correlation of strata. As such, it provides a method of correlation that is independent of other, more traditional, stratigraphic tools. Data for 10 major elements, 23 trace elements and 14 rare earth elements are acquired using ICP-OES and MS (inductively-coupled plasma - optical emission spectrometry and mass spectrometry) following a Li-metaborate fusion preparation. The sample preparation and analytical procedures used in this study are the same as those detailed in Pearce et al. (1999) and Jarvis and Jarvis (1995).

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Panel 2

Chem Unit 1 = characterized by low TiO_2/Nb values compared to overlying samples and generally higher Na_2O/Al_2O_3 values compared to Chem Unit 2.

Chem Unit 2 = characterized by higher TiO_2/Nb values compared Chem Unit 1, lower MgO/Al_2O_3 values than Chem Unit 4 and higher Na_2O/Al_2O_3 values than Chem Unit 5. Chem Unit 2 has generally higher K_2O/Rb values than Chem Unit 3.

Chem Unit 3 = thought to be chemically transitional between Chem Units 2 and 4. It is characterized by generally lower and upward decreasing K_2O/Rb values coupled with lower Na_2O/Al_2O_3 values compared to Chem Unit 2. Chem Unit 3 also has lower MgO/Al_2O_3 values than Chem Unit 4.

Chem Unit 4 = characterized by higher MgO/Al_2O_3 values than Chem Units 1-3 and higher Na_2O/Al_2O_3 values than Chem Unit 5.

Chem Unit 5 (Fluvial mudstones) = characterized by lower Na_2O/Al_2O_3 values and generally lower MgO/Al_2O_3 values compared to overlying and underlying units.

Chem Unit 6 = characterized by higher Na_2O/Al_2O_3 and MgO/Al_2O_3 values than Chem Unit 5.

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Panel 3

DISCUSSION

On Panel 2 the analyzed sections are all shown separately with all samples plotted relative to their measured position. On this panel all samples are plotted as a composite section (opposite), such that all samples assigned to Chem Unit 1 are plotted together, etc. However there is no implication of relative stratigraphic position within each Chem Unit. Both the chemical logs and the graphical plots show that each Chem Unit can be systematically differentiated from all others across the study area.

Although a total of 50 elements have been determined as part of the study a limited number key element ratios are sufficient to geochemically characterize the Ferron Sandstone Member. The probable mineralogical and therefore geological significance of the ratios are as follows:

MgO/Al_2O_3 = Relative chlorite abundance

Na_2O/Al_2O_3 = Relative plagioclase feldspar abundance

TiO_2/Nb = Relative abundance of Ti-rich volcanic material verses rutile (or illite)

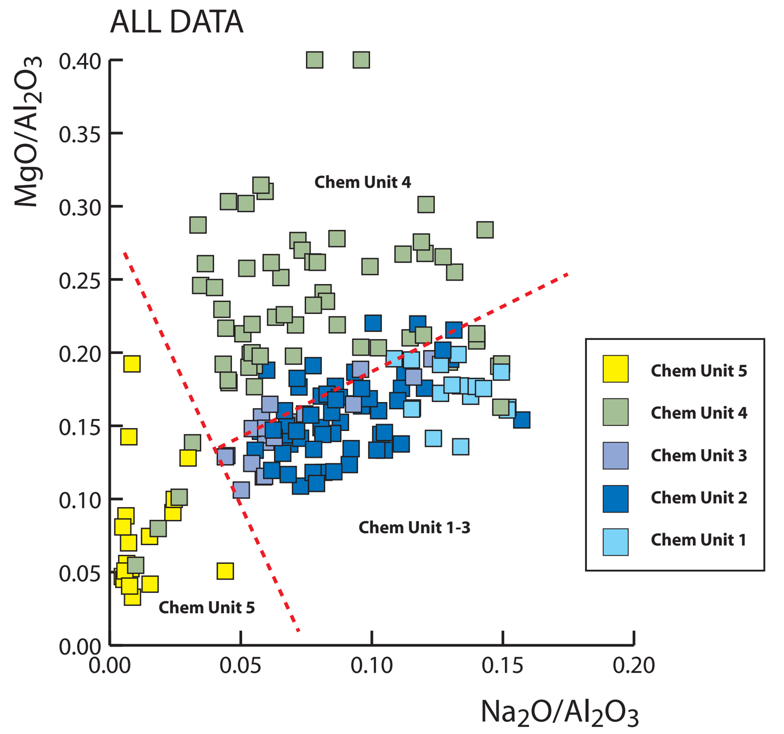
K_2O/Rb = Relative K-feldspar abundance verses illite

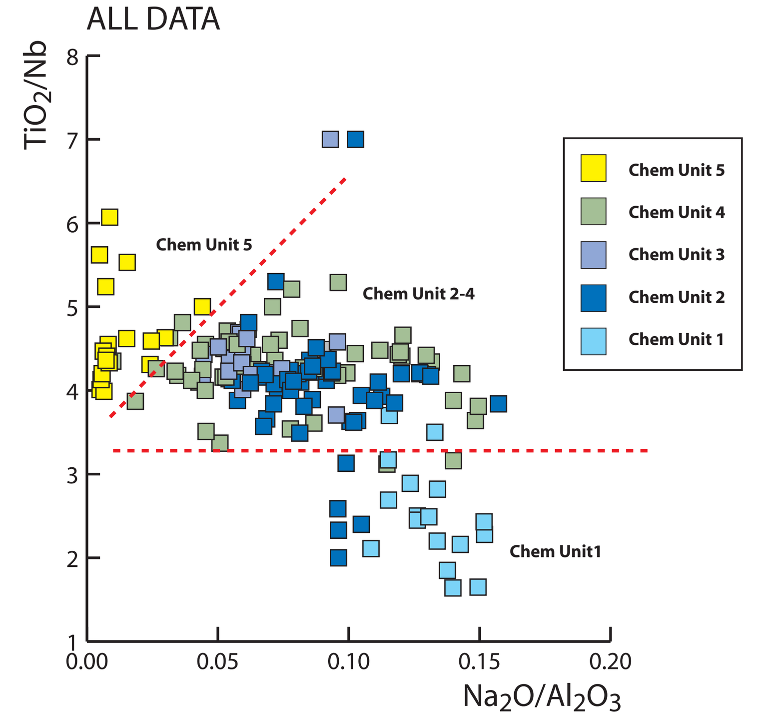
By combining the geochemical changes with the interpreted mineralogy, the following conclusions can be suggested:

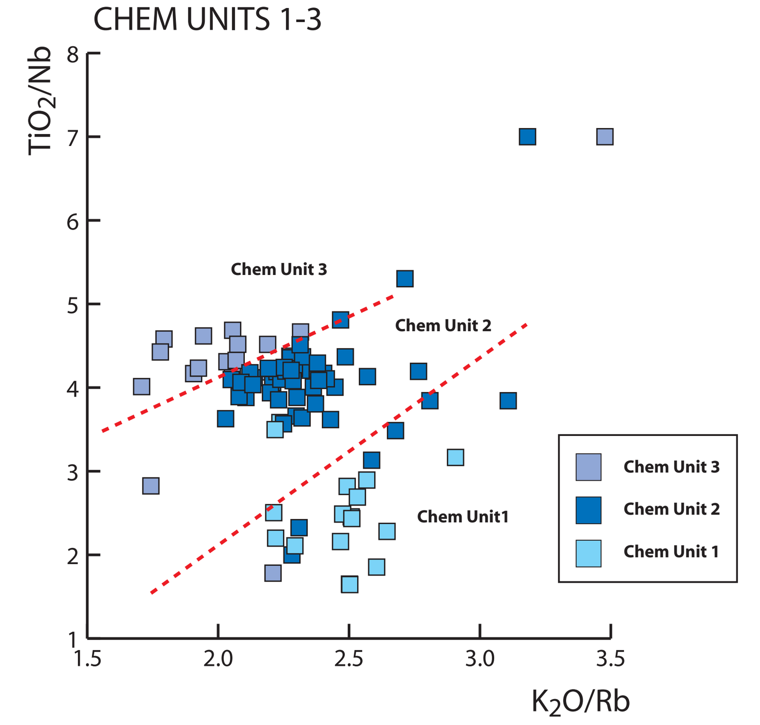
Chem Unit 1/Chem Unit 2 = Upward increase in Ti-rich volcanic material and decrease in plagioclase feldspar content.
Chem Unit 3 = is a transitional unit between Chem Units 2 and 4. From the top of Chem Unit 2 to the base of Chem Unit 4 K-feldspar decreases.
Chem Unit 3/Chem Unit 4 = Upward increase in chlorite content, suggesting a change in provenance.
Chem Unit 4/Chem Unit 5 = Upward decrease in plagioclase feldspar content, indicating either a change in sedimentary facies or a change in provenance.
Chem Unit 5/Chem Unit 6 = Upward increases in both plagioclase and chlorite contents, indicating major marine incursion.

DIFFERENTIATION

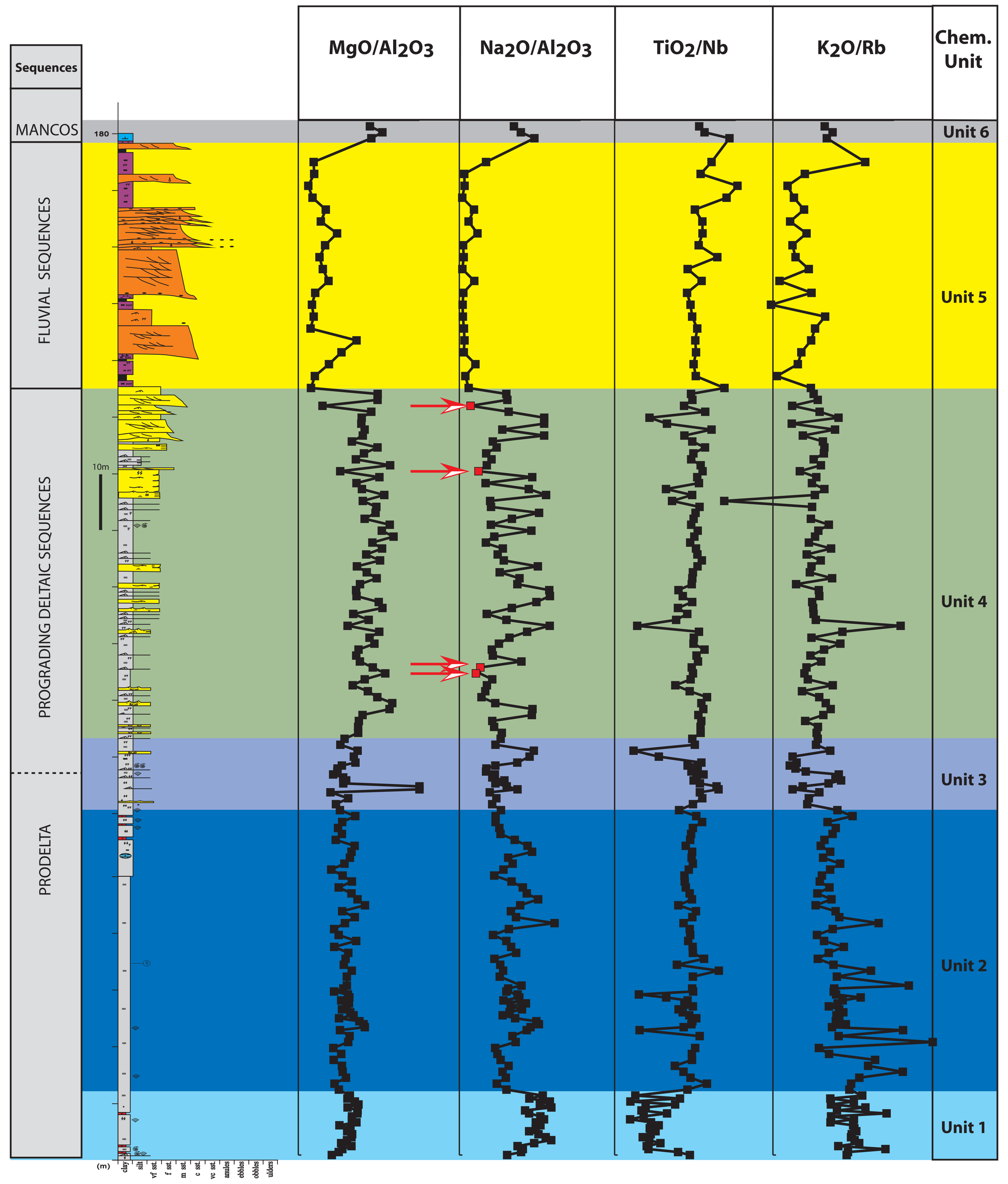
A series of binary plots have been constructed in order to geochemically differentiate Chem Units 1-5 (Chem Unit 6 is only represented by 3 samples and is currently not well characterized):







COMPOSITE SECTION

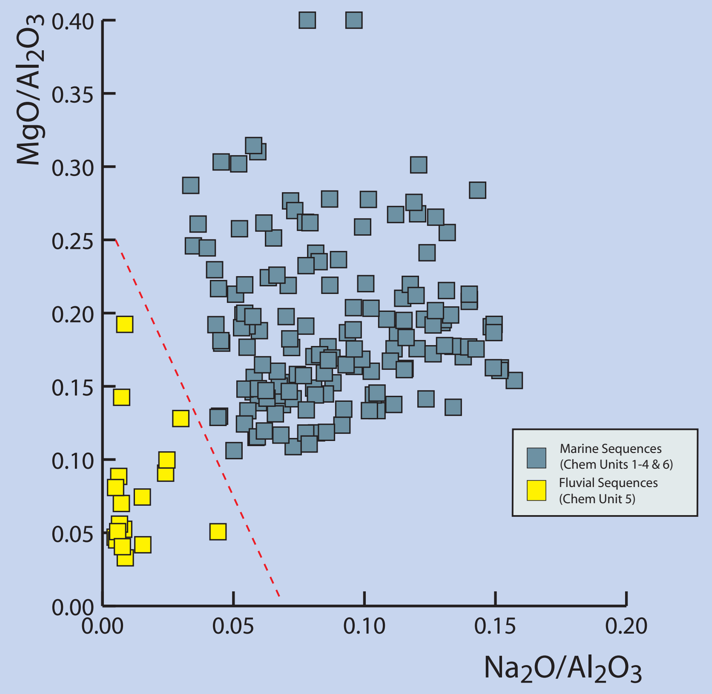


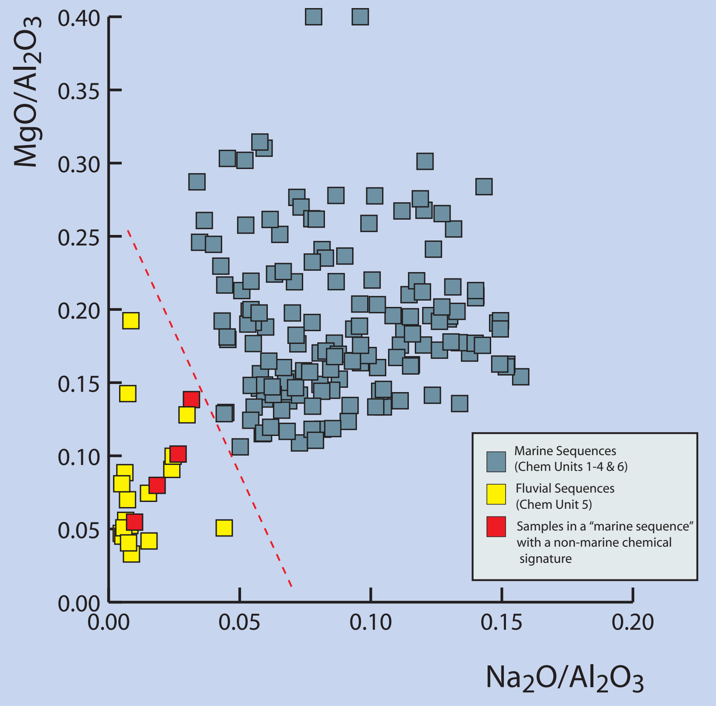
Arrows highlight silty-mudstone samples from Chem Unit 4, which plot with a chemical signature more similar to that typified by Chem Unit 5 samples.

Generally Chem Unit 4 has higher MgO/Al_2O_3 and Na_2O/Al_2O_3 values than Chem Unit 5, as shown on the chemical logs above and binary plots to the left. However, 4 samples within Chem Unit 4, (which are displayed as red squares on the chemical logs above and on the binary plot to the right) have values of MgO/Al_2O_3 and Na_2O/Al_2O_3 that are similar to those of Chem Unit 5.

Chem Unit 5 is a fluvially deposited sequence, while Chem Unit 4 represents marine shoreface environment. Therefore, the 4 highlighted samples within Chem Unit 4, may represent mudstones that have a fluvial chemical signature within a marine shoreface setting. One interpretation of this feature is that the Chem Unit 4 mudstones with a "fluvial" geochemical signature have been introduced into the shoreface environment by hyperpycnal flow during periods of river flooding. Therefore, the geochemical data in this study have the potential to identify hyperpycnites.

DIFFERENTIATION OF MUDSTONES FROM FLUVIAL AND MARINE FACIES





CONCLUSIONS AND RECOMMENDATIONS

The chemostratigraphic correlation and sequence stratigraphic correlation displayed on panel 2 are broadly similar, thereby demonstrating that the technique of chemostratigraphy is a viable stratigraphic tool for the characterization of mudstone lithologies in fluvio-deltaic sequences.

The composite chemical logs and binary diagrams (left) demonstrate that mudstones deposited in a fluvial environment are chemically different to those deposited in a marine environment.

The "Chem Unit" differentiation is based upon changes in MgO/Al_2O_3, Na_2O/Al_2O_3, TiO_2/Nb and K_2O/Rb ratios, all of which can be tentatively suggested to represent changes in provenance through time. Furthermore, the geochemical data suggest that marine mudstones have a different sediment provenance to fluvial mundstones. Additional mineralogical data, in the form of heavy mineral analysis, is needed to conform this supposition.

By enabling differentiation of marine and fluvial mudstone provenance this work has highlighted the presence of fluvially derived mudstones within demonstrably marine shoreface depositional environments. Their presence can tentatively be attributed to episodic fluvial flooding events that result in deposition of hyperpycnites. In order to test this hypothesis samples will be collected at 50cm spacing throughout a marine shoreface sequence, where hyperpycnites have been documented.

ACKNOWLEDGEMENTS

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