Proceedings World Geothermal Congress 2026, Calgary, Canada, June 8—11, 2026

Mineralogical and Geochemical Analysis of Select Alberta Basement Cores

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INTRODUCTION

Beneath the extensive sedimentary deposits of the WCSB, the crystalline rocks of Alberta's Precambrian basement remain poorly understood. Recently, this interval has drawn increasing attention due to its role in carbon capture and storage, its potential as an energy and mineral reservoir and its critical role in Enhanced Geothermal Systems. The Laurentian landmass forms the core of North America and records the complex tectonic history of the amalgamation of multiple Archean cratons and Proterozoic terranes. In Alberta, these tectonic assemblages become even more complicated (Fig. 1).

Although ~6,000 wells across Western Canada have reached basement rock, only ~600 have yielded valuable core samples. Our project analyses basement rock mineralogy from six of these cores, selected to represent four major domains: Buffalo Head Terrane, Taltson Arc, Medicine Hat Block and Loverna Block. The latter two of which are part of the Hearne Province.

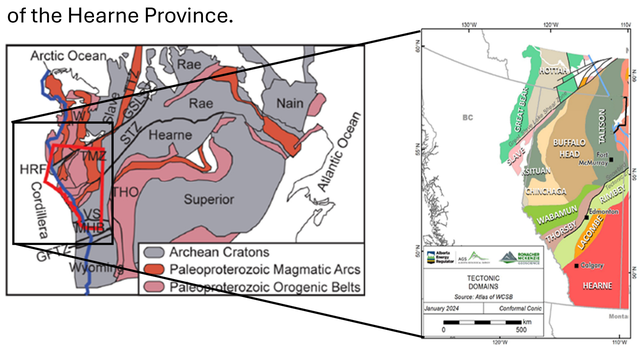


Figure 1: Tectonic map of Laurentia[1,2] (left); Main basement tectonic domains of Alberta[3] (right)

This project seeks to enhance the understanding of the unique mineralogical compositions across Alberta's basement rocks. Through systematic sampling, advanced analytical techniques, and comparative studies, the project aims to identify and characterize the mineral distributions specific to each region. By integrating these findings, the study will contribute to a more comprehensive knowledge base of Alberta's Precambrian basement, supporting applications in resource exploration and geological research.

METHODS

A total of six cores were chosen representing a diverse range of basement terranes (Archean craton, Proterozoic terranes and magmatic zones). Core that penetrated as deep as possible into the basement and that were least impacted by mechanical and chemical weathering were targeted. Figure 2 and Table 1 show the locations and history of each well.

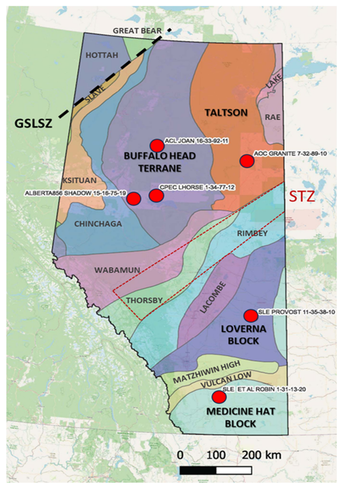


Figure 2: Map of Alberta basement terranes and major structural elements. Red dots show core locations for this project. GSLSZ = Great Slave Lake Shear Zone, STZ = Snowbird Tectonic Zone[2]

XRF was performed across the core at 30 cm intervals using a handheld analyzer . XRD was then run on 13 samples selected based on preservation quality and representation of the core. XRD analysis was performed using a Bruker D8 Discover with GADDs instrument.

Well	Name	Year Drilled	Status
01-31-013-20W4	SLE ET AL ROBIN 1-31-13-20	1985	Abandoned Zone
11-35-038-10W4	SLE PROVOST 11-35-38-10	1992	Suspended
15-16-075-19W5	ALBERTA856 SHADOW 15-16-75-19	1955	Abandoned
15-27-077-12W5	CPEC LHORSE 1-34-77-12	1987	Abandoned
07-32-089-10W4	AOC GRANITE 7-32-89-10	1994	Abandoned & Re-Entered
16-33-092-11W5	ACL JOAN 16-33-92-11	1985	Abandoned

Table 1: Well history for the six core included in the study

RESULTS & DISCUSSION

XRF data provided a reliable basis for estimating mineral percentages in the core samples (Fig. 3). Elemental compositions were processed using normative analysis software to convert geochemical data into mineralogical estimates. This allowed interpretation of complex datasets while maintaining transparency in the calculations and minimizing interpretive uncertainty. These results provide an important quantitative framework for comparing mineral compositions between samples and across basement domains.

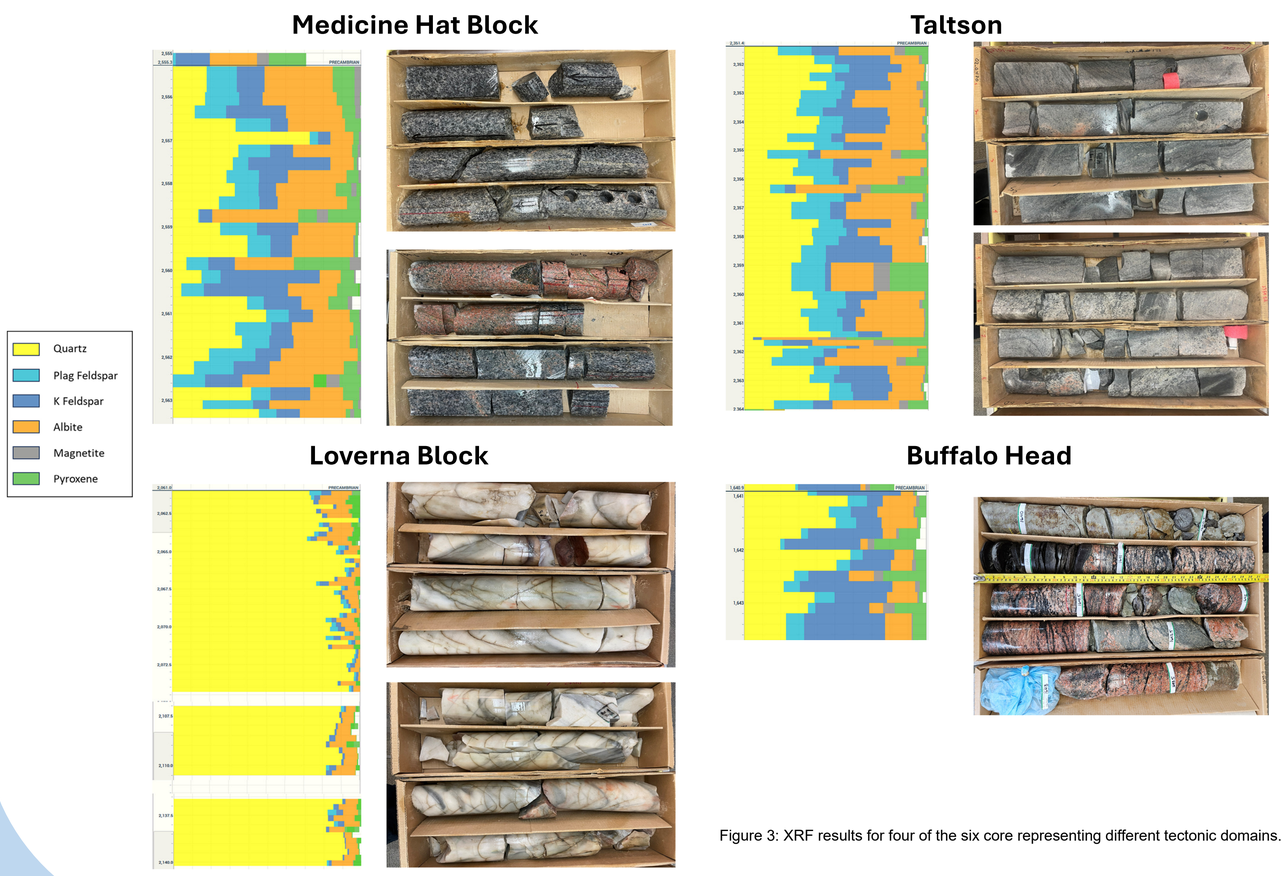
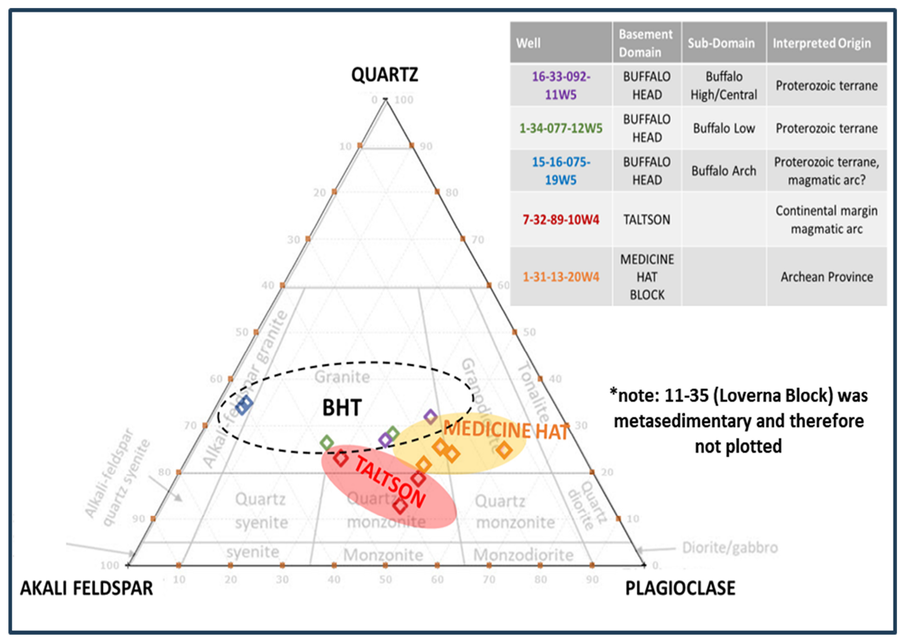


Figure 3: XRF results for four of the six core representing different tectonic domains.

XRD analysis complemented the XRF results by directly identifying the mineral assemblages present in the core. The mineralogical data were plotted on a QAP ternary diagram (Fig. 4) to classify the samples and visualize compositional relationships. The distribution of samples on the diagram reveals clustering patterns associated with specific basement domains and subdomains. These trends, highlighted by the coloured circled areas in Fig. 4, suggest systematic differences in mineral composition between regions, reflecting variations in the geological history and formation conditions of the basement rocks.



Well	Basement Domain	Sub-Domain	Interpreted Origin
16-33-092-11W5	BUFFALO HEAD	Buffalo High/Central	Proterozoic terrane
1-34-077-12W5	BUFFALO HEAD	Buffalo Low	Proterozoic terrane
15-16-075-19W5	BUFFALO HEAD	Buffalo Arch	Proterozoic terrane, magmatic arc?
7-32-89-10W4	TALTSON		Continental margin magmatic arc
1-31-13-20W4	MEDICINE HAT BLOCK		Archean Province

Figure 4. XRD data plotted on a QAP ternary diagram. Colour of the data points (diamonds) represent each well in the table. BHT = Buffalo Head Terrane

INTERESTING FINDS

Ferromagnetic minerals were identified in the 7-32-89-10W4 well (Talston)

- The amount of ferromagnetic minerals in Precambrian rocks varies based on factors like the rock's composition and the geological processes that formed the rocks
- Generally related to late- and post-collisional orogenic events
- Nearly half of the valuable mineral deposits in the world occur in the rocks of Precambrian shields

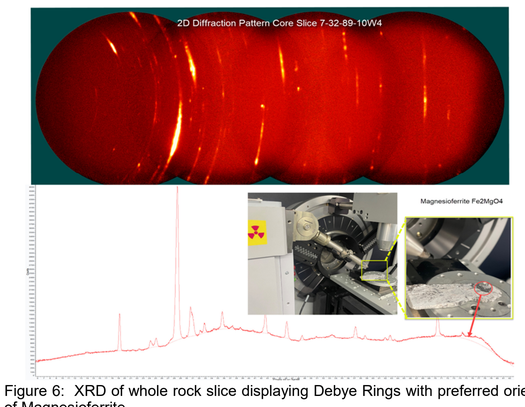


Figure 6: XRD of whole rock slice displaying Debye Rings with preferred orientation of Magnesioferrite

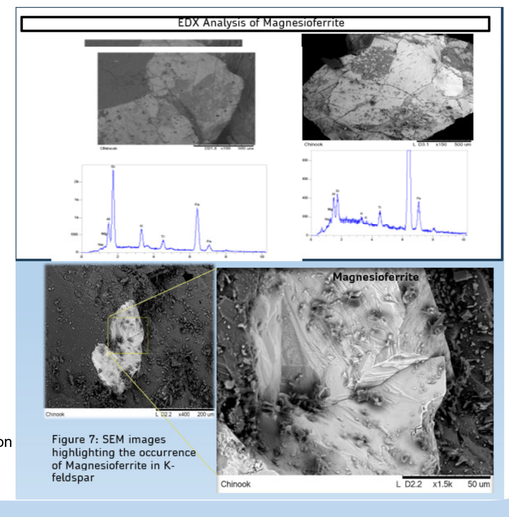


Figure 7: SEM images highlighting the occurrence of Magnesioferrite in K-feldspar

CONCLUSION

- The findings provide new insights into the mineralogical and geochemical composition of Alberta's Precambrian basement and complement previous work based on aeromagnetic surveys and U–Pb geochronology. By integrating this data this study helps refine interpretations of the structure and evolution of Alberta's crystalline basement.
- Identifiable trends in mineralogical composition across different domains and subdomains highlight variations in rock type, metamorphic history, and tectonic development. These patterns contribute to a clearer understanding of the geological processes that shaped the region and may help identify areas with potential for mineral resources and geothermal energy
- Future research can build on these results by expanding the dataset and further integrating mineralogical, geochemical, and geophysical information. Additional work may explore the implications of basement composition for energy development, resource exploration, and regional geological modelling within the Western Canadian Sedimentary Basin.
- Next step of study is to refine the current dataset through detailed petrographic analysis, which will allow for closer examination of mineral textures, grain relationships, and alteration features.

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