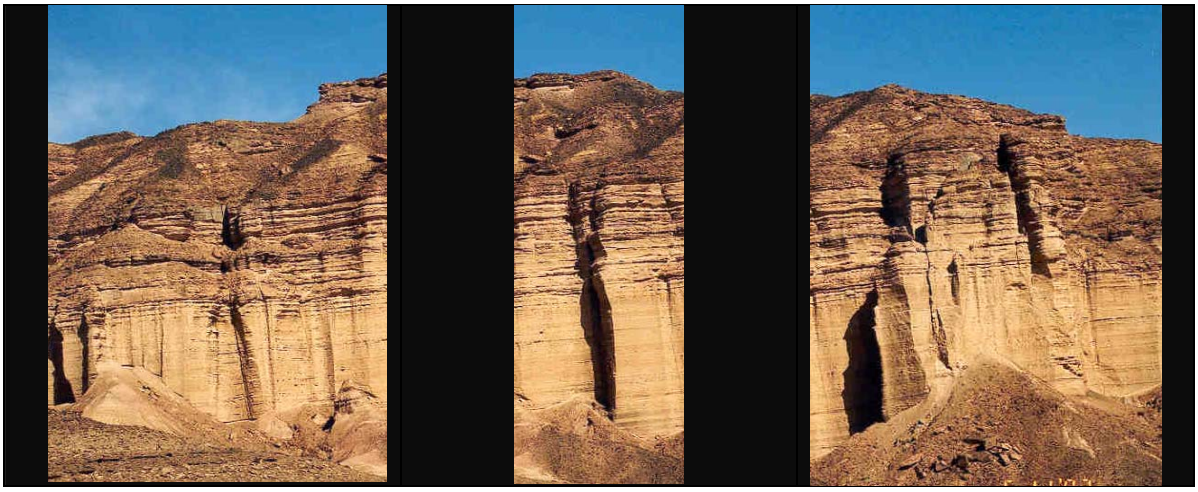
Trace Element Geochemistry and Heavy Mineral Assemblage of the Cambro-Ordovician Saq Sandstone of the Tabuk Basin and its Possible Correlation with the Wajid Sandstone of the Wajid Basin, Southwest Saudi Arabia

(KACST Project LGP 6-54)

Final Report

Mahbub Hussain, Ph.D.
Osman M. Abdullatif, Ph.D.

September, 2004



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Executive Summary

The lower Paleozoic sequences in Saudi Arabia are dominantly silicilastic, composed largely of medium to coarse-grained, cross-bedded sandstone of possible fluvial to deltaic origin. In the south and southwest, the Wajid Formation, considered the oldest formation in the region, overlies nonconformably on the Precambrian basement complex of igneous and metamorphic rocks. On the other hand, Saq Formation, which also nonconformably overlies the basement complex in central and northwestern part of the country, is the oldest formation. In fact, except for a small stretch of area close the middle, these two siliciclastic units appear to be part of a long, curvilinear belt of the exposed Paleozoic sequence that overlaps the eastern edge of the Arabian Shield. Subsurface geological and geophysical data included in several recent studies show that these two formations are laterally connected. However, in spite of overall lithological similarities, comparable stratigraphic position, and apparent physical continuity, these two Paleozoic units are considered two different formations and assigned separate names.

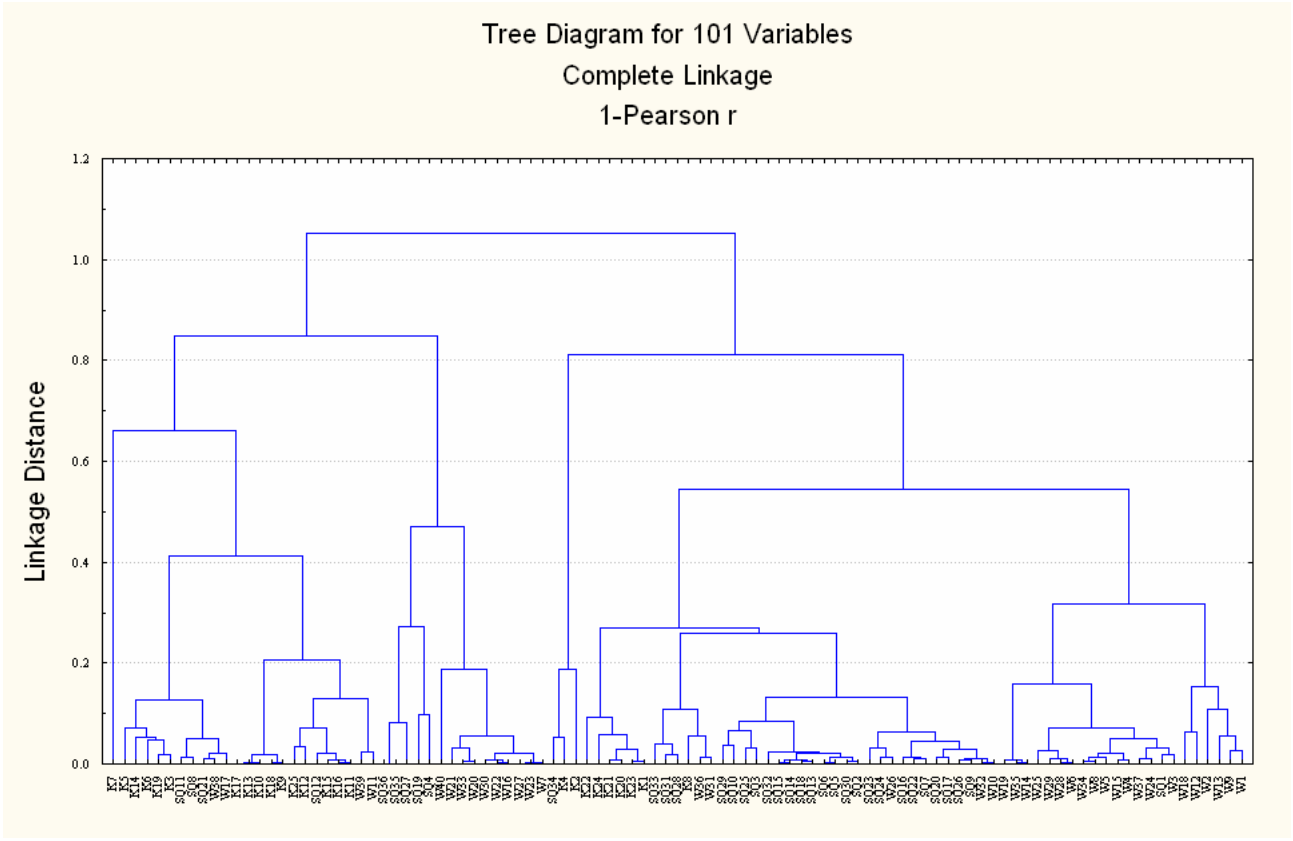
The present study is a geochemical approach involving elemental chemistry of selected trace and rare earth elements (REE) to determine the exact relationships between the Saq and Wajid Formation. The study also includes investigation of a third unit, the Kahfah member of the Ordovician Qasim Formation, to provide more validity to the geochemical database of these two lower Paleozoic formations and better understanding of their stratigraphic relationships, provenance and tectonic settings. Although the original proposal included heavy minerals as a possible tool for correlation, because of the limitations of the heavy mineral data, the interpretations and conclusions of this report are largely based on the elemental chemistry data of a total of one-hundred (100) sandstone samples (40 from the Wajid, 35 from the Saq, and 25 from the Kahfah, respectively) collected from the outcrop sections of these rock-stratigraphic units.

Selected elemental data including trace and REE were plotted as graphs, bivariate and ternary discriminatory diagrams not only to show the differences and similarities among the formations considered but also an understanding of their provenance and tectonic settings. In addition, multivariate statistical approaches of cluster and factor analysis were used to reveal any possible groupings of the samples based on their bulk elemental chemistry.

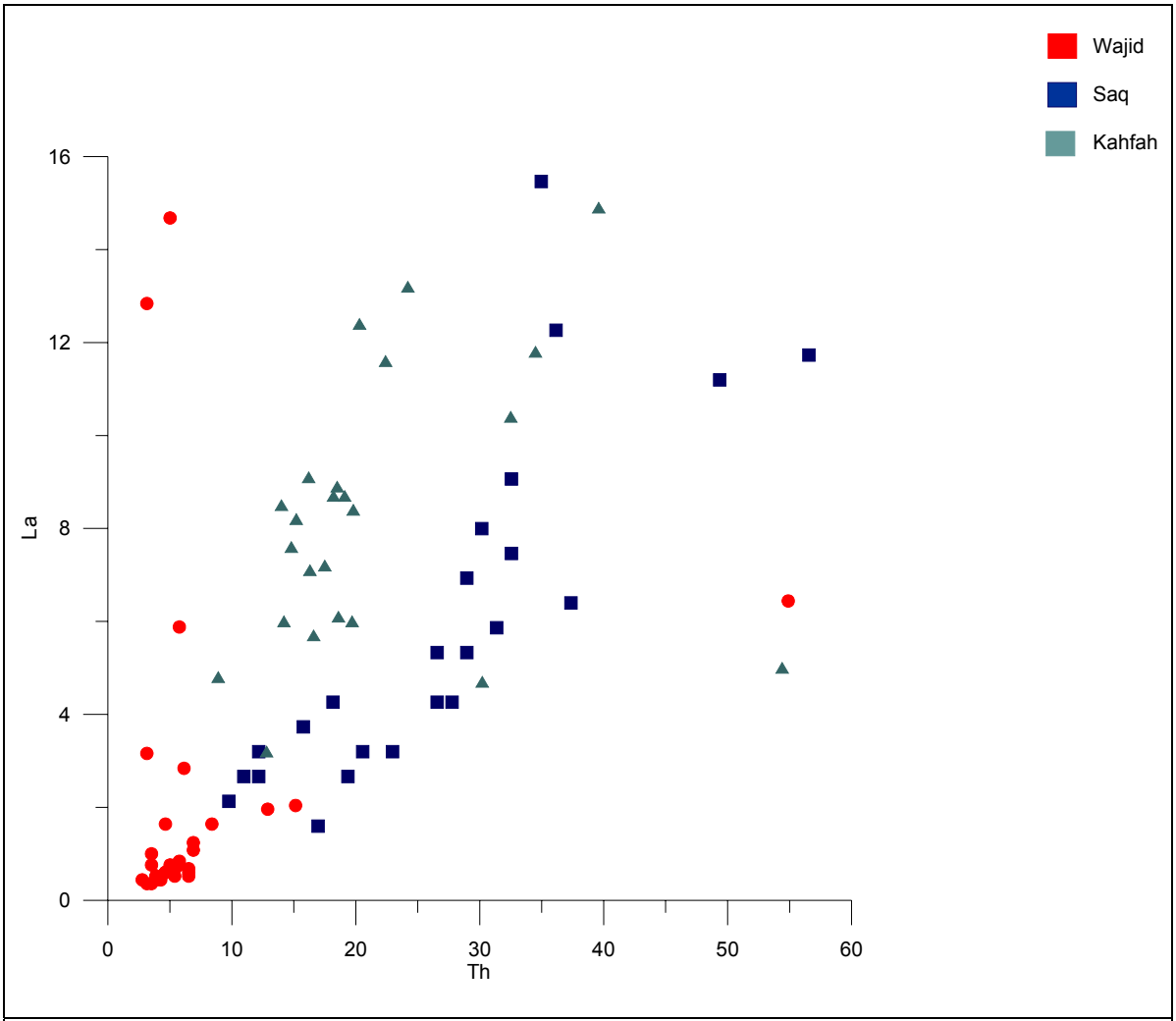
The elemental chemical data show that while the Saq and Wajid Formation, and the Kahfah member of the Qasim Formation contain common elements, the average concentrations of several elements including trace and REE are different. The elemental data show more similarities between the Wajid and Saq samples than between Saq and Kahfah or Wajid and Kahfah. Both cluster and factor analysis of the bulk elemental data confirms these relationships. Ternary plots of the factor analysis data show distinctive nature of these sample groups. The plots show overlapping of the Saq and Wajid samples between the end members. However, no such transitions are observed between the Wajid and Kahfah data, suggesting a weaker relationship between the Kahfah and the Wajid samples, and Saq Formation either a part of the Wajid Formation or a transition phase between the Kahfah member and the Wajid Formation.

Based on trace and REE chemistry data, a dominant supracrustal provenance and several different tectonic settings including, oceanic island arc, continental island arc and passive continental margin settings were interpreted for these rock-stratigraphic units. For example, based on the higher ratios of La/Y, the Wajid and Saq samples represent either of continental

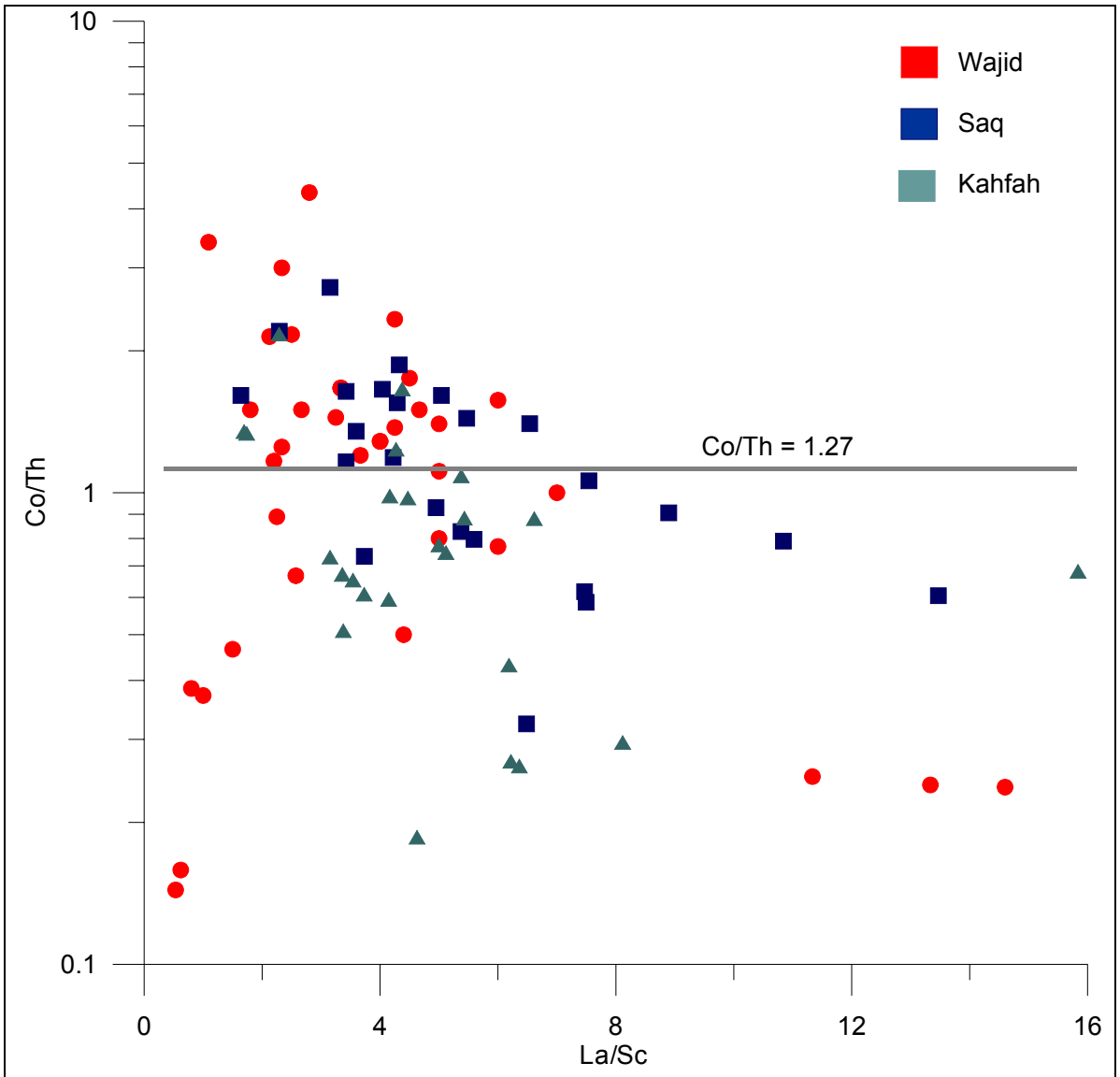
arc or passive margin setting. However, a low (less than 0.2) average ratios of Sc/Cr favors a passive continental margin, rather than active margin setting. Based on Th-Sc-Zr ternary plots, the samples from the Kahfah member of the Qasim Formation shows affinity to the oceanic island arc setting. On the other hand, majority of the Wajid and Saq samples suggest continental island arc to active continental margin settings.



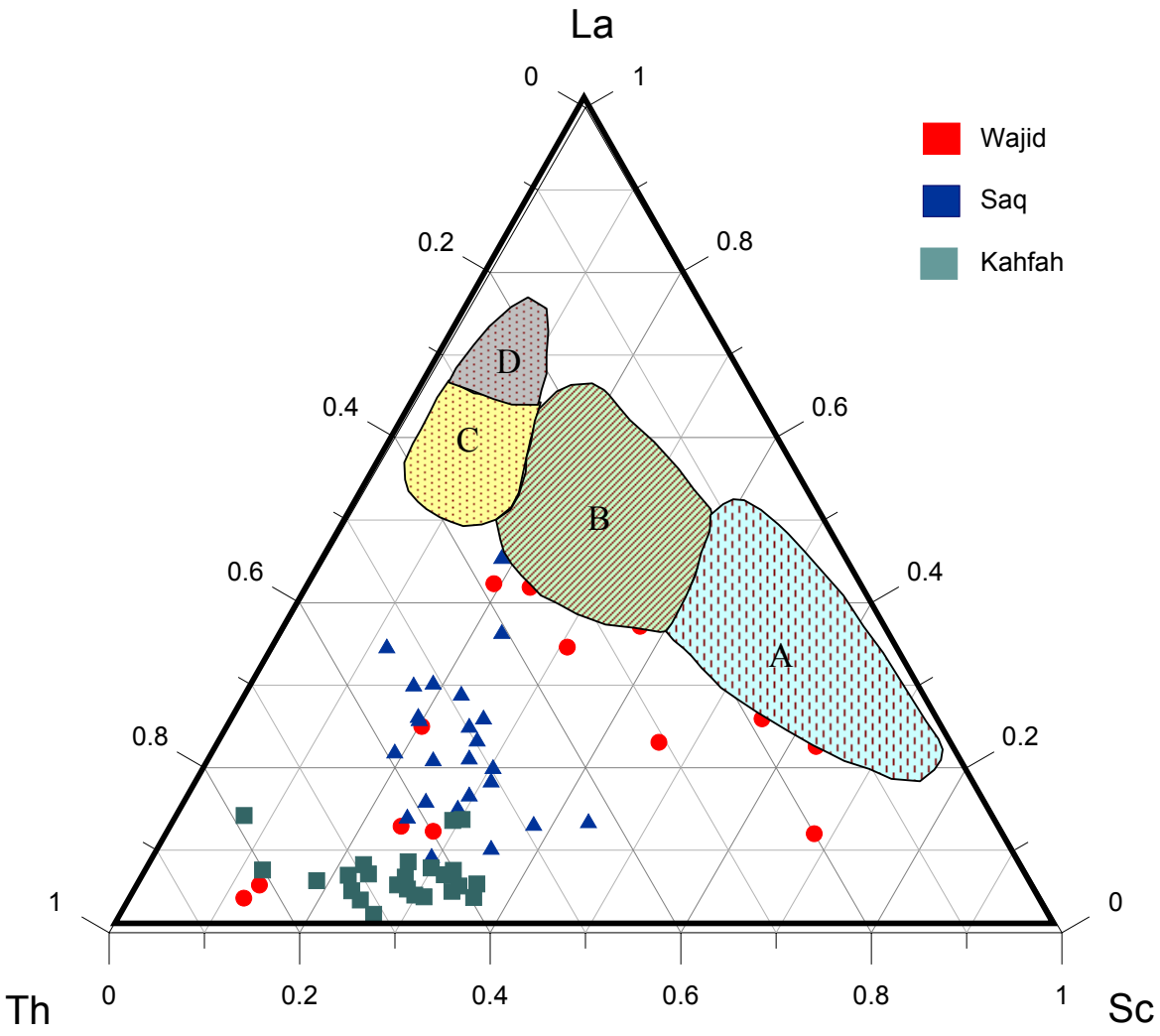
Cluster dendogram showing association of the samples. Note that most of the Wajid samples cluster at the right 1/3rd area of the dedogram, while the left 1/3rd of the dendogram is occupied dominantly Kahfah samples. The Saq samples occupy the transition zone between the Wajid and Kafhah samples. This distribution pattern may indicate significant difference between the Wajid and Kahfah formations, and the Saq Sandstone as the transition phase between these two groups.



Bivariate plots of the La vs. Th distribution in different sample groups. As shown on this figure (Figure 3.11a), the discriminatory fields based on La/Th ratios are well below the level of the active continental margin graywackes as defined after Bhatia and Crook (1986; Figure 3.11b). Color/Shape code: Red/Circle – Wajid, Blue/Sqaure – Saq, and Green/Triangle – Kahfah.



Bivariate plots of Co/Th vs. La/Sc raios. Note Co/Th ratio close to 1.27, and an overall scatter of the plots. Based on the low and relatively constant Co/Th ratios, and considerably variable La/Sc ratios, Saq and Wajid samples are interpreted (Taylor and McLennan,1985; Floyd and Leveridge, 1987) to have derived from a dominantly felsic source terrrain. Color/Shape code: Red/Circle – Wajid, Blue/Sqaure – Saq, and Green/Triangle – Kahfah.



La-Th-Sc ternary plots of different sample groups. According to Bhatia and Crook (1986), Gu et al., (2002) in such plots, active continental margin and passive margin samples fall close to the La end, while continental island arc samples fall close to the upper middle of the diagram and the oceanic island arc samples occupies the area close to the Sc end. Color/Shape code: Red/Circle – Wajid, Blue/Sqaure – Saq, and Green/Triangle – Kahfah.