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CORDILLERAN METAMORPHIC CORE COMPLEXES AND THEIR URANIUM FAVORABILITY

FINAL REPORT

Peter J. Coney and Stephen J. Reynolds

with contributions by
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Charles F. Kluth, Diane C. Ferris, James F. DuBois and James J. Hardy

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PREPARED FOR U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Resource Applications
Grand Junction Office, Colorado

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SUMMARY

By

Peter J. Coney and Stephen J. Reynolds

Cordilleran metamorphic core complexes are unique centers of plutonism, metamorphism, and deformation that are distributed in a discontinuous zone through the interior of the western United States. They are characterized by a distinctive assemblage of rocks and structures which occur in broad arch-like or domal features. They exhibit a central crystalline core of plutonic and high-grade metamorphic rocks. In high structural levels, these rocks are overprinted by a gently inclined mylonitic foliation containing a distinctive lineation. This lineation is typically consistent in trend over an entire mountain range or region. Near the margins of the crystalline core, the mylonitic rocks have been converted into a chloritic breccia via jointing, brecciation, faulting and hydrothermal alteration or retrograde metamorphism. The chloritic breccia is accompanied and overlain by a curvi-planar dislocation surface or décollement. Above the dislocation surface are an assortment of tilted and rotated rocks which generally lack any mylonitic fabric or metamorphic texture. These upper-plate rocks range in age from Precambrian to middle Tertiary and are cut by numerous low-angle structures which are inferred to be listric-normal faults that merge with or terminate against the underlying dislocation surface. A variation on this general theme occurs in several complexes where a zone of highly tectonized metasedimentary rocks (commonly marble) occupies the footwall of the dislocation surface.

Available geochronologic studies indicate a prolonged geological history for plutonic and metamorphic rocks of the crystalline core. However, it can generally be documented that final cooling of the crystalline core and movement on the dislocation surface are Tertiary! A Tertiary age for mylonitization is demonstrated for some complexes and can be inferred for many others. The genetic relationship between plutonism, metamorphism, mylonitization, and dislocation is currently controversial.

The uranium favorability of Cordilleran metamorphic core complexes is a function of processes that are either intrinsic or extrinsic to evolution of the complexes. Intrinsic processes include plutonism, metamorphism, mylonitization and formation of the dislocation surface (brecciation, hydrothermal alteration, tilting, etc.). Extrinsic processes such as weathering and sedimentation might have operated on rocks of the complexes before, during, or after the main phases of development of the complexes. Under favorable circumstances, both intrinsic and extrinsic processes are able to concentrate uranium into economically viable deposits.

The uranium favorability of Cordilleran metamorphic core complexes, as a group, is low. However, the favorability of individual complexes is as variable as their internal geology and regional tectonic setting. The Kettle, Selkirk and Albion complexes have the highest uranium favorability, while the remainder of the complexes have very low to moderate favorability.

Cordilleran metamorphic core complexes are in general most favorable for pegmatitic, metamorphic, hydrothermal, authigenic, allogenic, and peripheral lacustrine uranium occurrences. The complexes may be significant sources of uranium for later redistribution and concentration. Of particular importance in this regard are dislocation zones on the flanks of the complexes which may have been permeable channels or depositional sites for ascending (hydrothermal) or descending (meteoric) uraniferous fluids. The uranium potential of such zones is unknown and will only be revealed by exploratory drilling down-dip from uraniferous core rocks. Additional detailed study is needed to further document the uranium favorability of individual metamorphic core complexes.

ACKNOWLEDGMENTS

The Principal Investigators are very grateful for the cooperation and efforts of many individuals who participated in the completion of this report. George Davis and Paula Trever, Department of Geosciences, University of Arizona and Stanley Keith, Arizona Bureau of Geology and Mineral Technology made significant contributions to the main scientific thrust of the project. Steven H. Lingrey and Charles F. Kluth, Department of Geosciences, University of Arizona did much of the original map compilations which appear on the 1:1,000,000 and 1:250,000 tectonic maps. Dianne C. Ferris, Department of Geosciences, University of Arizona compiled the bibliography and prepared the uranium occurrence lists and was always ready to provide any assistance needed. James F. Dubois was responsible for the thin-section petrography. Victoria V. Schale, Karl S. Tsuji, Rex A. Knepp, and Nancy Riggs did the drafting for the report. Sandra Hallenbeck, Administrative Assistant, Department of Geosciences, University of Arizona organized the logistics for final preparation of this report. Pat Bougie patiently coordinated and performed the typing. Richard L. Armstrong of the University of British Columbia, Greg A. Davis of the University of Southern California, Ed DeWitt of the Pennsylvania State University, and Wesley Peirce and Robert Scarborough both of the Arizona Bureau of Geology and Mineral Technology were most cooperative in providing unpublished data and helpful discussion which improved significantly the final product of this project.

We are all deeply grateful to John Burger of Bendix Field Engineering Corporation who was always most helpful and supportive and very patient throughout the entire project. We deeply appreciate the opportunity to carry out this study which because of its timeliness has considerably improved our understanding of Cordilleran metamorphic core complexes.

INTRODUCTION

by

Peter J. Coney and Stephen J. Reynolds

GENERAL STATEMENT

Cordilleran metamorphic core complexes are characterized by shallow-dipping foliation-lineation arches and domes composed of metamorphosed, migmatized and anomalously deformed rocks whose protoliths can range from Precambrian to middle Tertiary in age. Most have plutonic bodies within them and late-stage granitic rocks, frequently of two-mica composition with aplitic and pegmatitic phases, are common. All the complexes are associated with high-level décollement or dislocation zones and listric normal faults in an unmetamorphosed cover terrane. Much of the deformation in the cover as well as in the metamorphosed core zone can be proven to have occurred in Tertiary time. Early to Middle Tertiary basinal continental sedimentary rocks and associated caldera related volcanic rocks are common on margins of the complexes. These sediments and volcanics are usually tilted to high angles by listric normal faulting. Geochemistry and geochronology in core-zone rocks is always complex and radiometric age determinations can range from 2 billion to as young as 11 million years. Cordilleran metamorphic core complexes are found in a rather narrow sinuous belt along the so-called "hinterland" of the eastern part of the North American Cordillera from southern Canada southward into Sonora, Mexico. Over 25 complexes are now recognized most of which have only been identified since 1970. The features are presently surrounded by considerable controversy and there exists conflicting opinion as to their timing and mechanism as well as to their regional tectonic significance.

As awareness of these newly recognized tectonic features became more widespread the question was asked as to what economic significance they might have. One of the first things that came to mind was their possible uranium potential. The reasons for this were, in the minds of some, both theoretical and observational.

A theoretical basis for a high uranium potential seemed to rest largely on the evidence for remobilization of pre-existing continental crust and on the widespread presence of granitic plutons of a two-mica type, that are characterized by extensive late-stage, residual phases of alaskite, pegmatite, and aplite. This type of pluton was believed by some to have anatectic origins and a high potential for late-stage concentrations of uranium. Also, it is probable that hydrothermal and meteoric processes in the complexes were capable of further concentration of uranium in adjacent sedimentary basins.

The observational basis for a possible high uranium potential was suggested by the fact that many known occurrences of uranium are clearly associated with a metamorphic core complexes, although previous workers had not recognized the relationship, mostly because the complexes had not been recognized for what they were. Also, there has been much interest in the Rossing uranium deposit of southwest Africa which is classified by Bendix as "Anatectic" and which is associated with a "gneiss dome". Since some felt that the complexes were in fact gneiss domes interest was aroused in the complexes as possible sources of uranium. It was in the above context that the Department of Geosciences of the University of Arizona was approached by Bendix Field Engineering Corporation to provide a study of Cordilleran metamorphic core complexes and their uranium favorability as part of their World Class Studies program on uranium resources.

OBJECTIVES AND SCOPE OF THIS REPORT

The objective of this report is to provide a descriptive body of knowledge on Cordilleran metamorphic core complexes including their lithologic and structural characteristics, their distribution within the Cordillera, and their evolutionary history and tectonic setting. We also examine the occurrance of uranium in the context of possibility for uranium concentration.

Chapters 1-3 deal with the basic geologic data on the complexes and related features while Chapters 4-6 deal with uranium distribution and potential of the complexes in western United States. Chapter 1 is an overview of Cordilleran metamorphic core complexes which describes their physical characteristics, tectonic setting and geologic history. This overview is accompanied by a tectonic map at a scale of 1:1,000,000 of the core complex belt (Map 1-1). Chapter 2 is a discussion of the mantled gneiss dome concept. The purpose of including this work is to provide a basic history of this concept and to describe the characteristics and distribution of gneiss domes throughout the world to enable one to compare and contrast them with the metamorphic core complexes as discussed in this report. Since some gneiss domes are known producers of uranium (as are also some core complexes) we felt it would be productive to include a discussion on them. Chapter 3 is an examination of the effects of the core complex process on adjacent sedimentary and volcanic cover terranes which can extend over 100 kms. beyond the exposed cores of the complexes themselves. Also included is a discussion of the kinematic significance of these cover terranes as they are related to process within the cores of the complexes. Since some of the cover terranes have uranium prospects in them we include a discussion of them. Chapter 4 is a detailed discussion of uranium in Cordilleran metamorphic core complexes and includes the conceptual basis for the various types of occurrences and the processes that might favor concentration of uranium.

The report is supported by a 5-part Appendix. Appendix A is a complete annotated bibliography on Cordilleran metamorphic core complexes, gneiss domes in world geologic literature, and any geologic-tectonic sources relevant to the core complex problem. Appendix B is an annoted bibliography on the uranium aspects of metamorphic core complexes, gneiss domes, and two-mica granites. Appendix C is a listing of uranium occurrence in the core complex belt of western United States and is accompanied by 1:1,000,000 scale maps of each of the states within which the belt occurs, showing the locations of the uranium occurrences included in the list. Appendix D is a geologic and uranium distribution summary of each of the core complexes accompanied by a tectonic-geologic map of each of the complexes at a scale of 1:250,000. In this section the uranium favorability of each complex is discussed. Appendix E is a data list of sample locations, geochemical data, and petrographic descriptions.

It is worth pointing out in conclusion that the majority of the core complexes discussed in this report either do not appear or are not recognizable on existing published geologic maps. They are, without question, the newest addition to the recognized architecture of the Cordillera. This report is an attempt to rectify the inadequacy of existing information and to provide a basis to access both their economic as well as scientific potential.