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ScienceDirect
Journal of Geochemical Exploration 91 (2006) 27–40
JOURNAL OF GEOCHEMICAL EXPLORATION
www.elsevier.com/locate/jgeoexp

Thermal and isotopic profiling of the Pipeline hydrothermal system: Application to exploration for Carlin-type gold deposits

Greg B. Arehart [a,*], Raymond A. Donelick [b]

[a] Department of Geological Sciences, University of Nevada, Reno, Reno, NV 89557, United States
[b] Apatite to Zircon, Inc., 1075 Matson Rd., Viola ID 83872, United States

Received 9 March 2005; accepted 28 December 2005
Available online 20 March 2006

Abstract

New exploration techniques are vital to the search for new orebodies in mature terranes, as well as for extensions of existing orebodies. This research focused on application of low-temperature dating techniques (primarily apatite fission-tracks) and stable isotope measurements (carbon and oxygen in carbonate rocks) in and around the Pipeline deposit, a Carlin-type gold system. The primary purpose of the project was to assess whether these techniques could provide exploration vectors that might be used in conjunction with other geologic, geochemical, and geophysical techniques to determine the locus of fossil hydrothermal fluid flow, and the attendant possibility of finding economic mineral deposits.

At Pipeline, measurements of apatite fission-tracks and (U−Th)/He geochronometry yield a clear indication of the elevated temperatures associated with the fossil hydrothermal system. The pattern is one of a central target (Pipeline deposit) with decreasing thermal effects as far as several kilometers laterally from the known ore zone. Because of the irregular nature of fluid flow through fractures, a significant number of samples are required to discern this pattern, but the pattern is quite clear from the 32 samples in and around the Pipeline pit.

Stable isotope measurements of carbonate rocks yield patterns centered on the Pipeline pit area. Oxygen isotopes in particular are shifted toward lower values as the result of interaction between the hydrothermal fluids and carbonate rocks. Carbon isotopes show a pattern, but it is somewhat more difficult to interpret than the oxygen isotope pattern. As with the geochronometric patterns, isotopic indications of fluid flow are present several kilometers from the ore zone at Pipeline. Also as with the geochronometric data, a relatively large sample set is required to see the pattern. At Pipeline, the patterns are evident in approximately 45 surface samples and very clearly in the cross-sections containing approximately 100 samples.

From these data, it is clear that thermal and stable isotopic measurements on rocks at a significant distance from the known Pipeline hydrothermal system record the passage of hot fluids through the rock. Both techniques provide a footprint of the Pipeline system that is several diameters larger than the ore zone (as presently known). Therefore, thermochronologic and stable isotopic measurements can be utilized in conjunction with other techniques as part of an overall exploration strategy for Carlin-type deposits. Although these techniques do not provide a direct indication of the metal content of the fossil hydrothermal fluids, they do provide an indication of the robustness of fluid flow and the potential size of a hydrothermal system.

Keywords: Stable isotope; Carlin-type; Fission-track

* Corresponding author. Fax: +1 775 784 1833.
E-mail address: arehart@unr.edu (G.B. Arehart).

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doi:10.1016/j.gexplo.2005.12.005

1. Introduction

Hot fluids flowing through fractured rocks should leave two clear signals of their passage: a thermal signature and a geochemical signature of various types. Traditional geochemical exploration methods have emphasized trace element geochemical signatures as indicators of past hydrothermal activity and metal potential. Although these methods can be very effective, they are generally limited in their areal extent, when compared to isotopic and thermochronological methods described herein.

Under ideal circumstances, one would like to see the most effective and compressed depositional mechanism possible in a metal-bearing hydrothermal system, as such a mechanism would maximize the metal contained within a minimal volume, therefore yielding a high-grade deposit with a sharp boundary. However, for trace element geochemistry to work as an exploration tool requires that these trace metals in the hydrothermal fluids be deposited peripheral to the main ore zone, yielding a metal halo that is significantly larger than the ore zone. In most orebodies, this dispersion of metals has occurred to varying extents away from the ore zone, with the size of the halo being dependent on a number of parameters such as the metal content in the fluid, reactivity of the rock, and efficiency of the depositional mechanism(s). In any case, as metals are deposited further from the main ore zone, the metal contents of the rocks through which fluids are flowing eventually approach background levels.

Carlin-type gold deposits (CTDs) in Nevada have distinctive geochemical and alteration signatures that have been utilized to vector exploration efforts. The metals, other than Au and Ag, that have been historically utilized in exploration for these deposits include As, Sb, Hg, Ba, and Tl; more recent data suggests that other metals such as Zn might also provide exploration value, but the distribution patterns of these other metals is less clear. However, those metal signatures appear to be of relatively limited extent (1–2 km) beyond the ore zone, probably because of the reactivity of the host carbonate rocks. Alteration effects associated with Carlin-type deposits include the formation of jasperoids and related silicification, and decarbonatization of the calcareous host rocks (e.g., Arehart, 1996; Hofstra and Cline, 2000). These alteration effects are rarely found more than a kilometer from ore. It is desirable to develop additional exploration tools that might allow detection of paleothermal anomalies in rocks that do not exhibit anomalous geochemical signatures and appear (visually/trace element geochemically) only marginally altered or unaltered.

The purpose of the research described below was twofold: 1) to investigate the nature and extent of thermal and isotopic effects of Carlin-type hydrothermal fluids on surrounding wallrock at a deposit and regional scale; and 2) using our understanding of these effects, to develop a broader vectoring tool for exploration than is known at present. This paper presents the results of a deposit-scale study of apatite fission-tracks and stable isotope geochemistry of carbonate rocks in the Pipeline deposit, a Carlin-type gold deposit in north-central Nevada.

2. Geology of the Pipeline deposit

The Pipeline deposit is located in the Cortez trend, approximately 130 km southwest of Elko, NV, near the historic Carlin-type deposits at Cortez and Gold Acres (Fig. 1). The Pipeline deposit was chosen for this study because of its relatively simple geology; the deposit is within only two flat-lying sedimentary rock units which are geochemically very similar; there are no known igneous rocks within the deposit itself (although one pluton outcropped in the Gold Acres pit to the W of Pipeline), and the amount of structural disruption is relatively minimal. In addition, there are significant surface exposures as well as extensive drill core that provided a relatively extensive sample suite.

The deposit occurs in an erosional window through the Roberts Mountains thrust in the Silurian–Devonian Roberts Mountains Formation and/or the Devonian Wenban Formation and was covered by 15–100 m of alluvium (Foo et al., 1995a,b). The Roberts Mountains

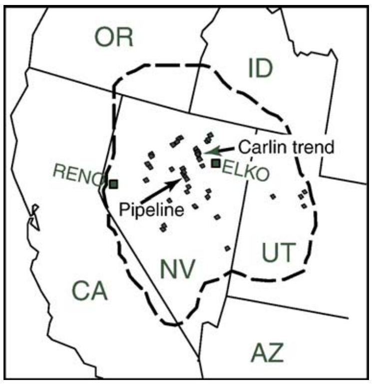

Fig. 1. Location map showing the Great Basin (dashed line), Carlin-type deposits (black diamonds), the Carlin trend, and the Pipeline deposit. Pipeline is within a NNW-trending linear array of Carlin-type deposits known as the Cortez trend or Battle Mountain–Eureka trend.