COMPARATIVE GEOLOGY AND GEOCHEMISTRY OF SEDIMENTARY ROCK-HOSTED (CARLIN-TYPE) GOLD DEPOSITS IN THE PEOPLE'S REPUBLIC OF CHINA AND IN NEVADA, USA

by

Zhiping Li *and* Stephen G. Peters

Abstract

Sedimentary rock-hosted (Carlin-type) gold deposits have been considered economically significant and geologically distinct since the early 1960's. Similar deposits have been discovered in P.R. China, Australia, Dominican Republic, Spain, Russia, Malaysia, Philippines, Yugoslavia, and Greece, *in* addition to the Great Basin, US. This report contains data on 113 sedimentary rock-hosted gold deposits (prospects) in southwest and central People's Republic of China. Of these, at least 19 deposits are of substantial tonnage, making P.R. China the second leading country to the United States in exploiting these deposits. A new Proterozoic age sedimentary rock-hosted gold deposit in northeastern P.R. China also is described.

Chinese sedimentary rock-hosted deposits are mainly located along the margins of the Precambrian Yangtz craton. Their distribution is controlled by regional rifts, whereas secondary structures, such as short-axial anticlines, high-angle faults, stratabound breccia bodies, and unconformity surfaces, also are favorable host structures. The deposits are found in sedimentary formations of Paleozoic to Cenozoic age, and local deposits in the northeastern part of China are hosted in Proterozoic age rocks. Impure limestone, siltstone, and argillite are the host rocks for ore. Alteration types are silicification, decalcification, argillization, carbonization, and locally albitization. Igneous intrusions usually are not present near most Chinese deposits, except for local lamprophyre and silicic dikes.

Gold is disseminated in sedimentary rock-hosted gold deposits. The main opaque minerals include gold, electrum, pyrite, arsenopyrite, stibnite, orpiment, realgar, and cinnabar; gangue minerals are quartz, barite, organic carbon, carbonate and clay minerals, and local albite. Elements associated with gold in Nevada deposits, As, Sb, and Hg, also are closely associated with the Chinese deposits, but U deposits also are associated with some gold deposits in China, and platinum group elements (PGEs) also locally are enriched to economic levels in some of these deposits. Low salinity fluid inclusions (3 to 9 wt. percent NaCl equivalent) and limited stable isotope data suggest possible multiple sources of metallogenic fluids in the Chinese deposits, similar to those in Nevada. Trapping temperatures vary from 165 to 290 °C, and pressures of formation range from 52 to 560 bars, *in*dicating that Chinese Carlin-type gold deposits formed at or below the epithermal environment.

INTRODUCTION

The purpose of this paper is to describe a representative group of Chinese sedimentary rock-hosted gold deposits, and to compare them with similar (Carlin-type) deposits in Nevada. The main sources of information about the Chinese deposits are from 1980's and 1990's literature, both in English and in Chinese, and also data collected by the authors from a field trip to selected Chinese Carlin-type gold deposits in August, 1997. We hope this will be helpful for geologists who are interested in the study, exploration, and mining of Chinese Carlin-type gold deposits and in sedimentary rock-hosted gold deposits in general.

By the later part of the 1900's, sedimentary rock-hosted gold deposits became an important economic issue and an international academic research topic. Their origin is not well understood, and is a much-debated topic (see Vikre and others, 1997). Why are geologists motivated to study Carlin-type deposits? One reason is that the study of these deposits may help develop important innovations in metallogenic theory and in exploration methods for gold deposits. Secondly, many of these sedimentary rock-hosted gold deposits are large and have been part of a high discovery rate in Nevada over the past 25 years. Thirdly, similar gold deposits have been found in other countries besides the United States. In particular, more than one hundred similar deposits found in China make it possible to apply comparative research on Carlin-type gold deposits, and to develop a better understanding of the genesis of these deposits.

Recognition of Carlin-type gold deposits as a separate class of sedimentary rock-hosted gold deposits has been a significant event in the history of the science of economic geology, not only because of their large economic value, but also because this recognition has brought an important advancement to the field of economic geology in terms of exploration using a Carlin-type genetic ore deposit model. Traditional metallogenic theory has previously dealt with gold deposits contained in quartz veins that formed in igneous or metamorphic rocks (see Boyle, 1979, 1987; Bache, 1987). However, Carlin-type gold deposits are mainly hosted in sedimentary rocks, such as limestone, siltstone, argillite, and shale. Gold contained in them is micron-size, usually associated with arsenic-rich pyrite. One traditional exploration method for gold deposits is prospecting by tracing gold placers to their source. This has not worked in exploration for Carlin-type deposits (Tu, G.Z., 1994; Liu, K.Y., 1991), because the gold particles are so small that detectable gold in placers is not present downstream.

The discovery and exploitation of sedimentary rock-hosted gold deposits in Nevada has created significant wealth, jobs, and industry services, and has expanded cities. These deposits have made a large contribution to the economy of Nevada, as well as the USA. The large, rich, gold deposits along the Carlin trend, Nevada, a major elongate cluster of deposits, are a significant contributor to the United State's resource-based growth. Although their origin is incompletely understood, a number of features, *in*cluding field relations at all scales, age relations, and geochemical and isotopic characteristics, bear on the origin of these deposits. Previous genetic models have been developed from mining the oxide or weathered parts of these systems in Nevada over the last two decades. Recent extensive exposures of unoxidized parts of the deposits provide new evidence that leads to consideration of additional hypothesis of their origin, particularly those that incorporate the role of small- and large-scale deformation of the ores and surrounding rocks.

Over 100 similar gold deposit occurrences have been found in southwest and central China since the first Carlin-type, the Shixia gold deposit, was identified there between 1964 and 1966 (see Liu, D.S. and Mao, 1994); of these, at least 19 are of substantial grade and tonnage. Since the 1980's, Chinese geologists have devoted a large-scale exploration and research effort to the Chinese Carlin-type gold deposits; these studies have been sponsored by the Bureau of National Gold Administration, Ministry of Metallurgical Industry, Ministry of Geology and Mineral Resources, Chinese Academy of Sciences, Chinese Non-ferrous Metal Industrial General Company, and other Chinese government agencies. As a result, there are more than 20 million ounces of proven gold reserves in sedimentary rock-hosted deposits in P.R. China and additional estimated and inferred resources also are present in numerous occurrences and prospects. This makes China second to Nevada in contained ounces of Au in Carlin-type deposits (see Liu, D.K, 1991).

Compared to Nevada deposits, Chinese sedimentary rock-hosted gold deposits are smaller in size, contain a shallower oxidation zone, and thus consist of dominantly refractory ores. However, this creates an opportunity for geologists to study the hypogene zones of the Chinese deposits to better understand those oxide deposits in Nevada. In addition, due to strict environmental regulation, and high labor costs, more and more western companies have started to move their mining interests to China, Mongolia and Asia where extraction costs are less expensive. Most Chinese sedimentary rock-hosted gold deposits are in an undeveloped state or are being exploited by small-scale mining by manual and mechanical methods (figs. 1, 2, 3, and 4). This is because of their refractory nature and because of the lack of financial capital. Therefore, *in* consideration of the needs from both economic geologic science and industry, it is necessary for geologists to do systematic comparative research on the Chinese deposits with respect to the relatively better-documented and studied deposits in Nevada. Such research is hampered by a lack of international cooperation, translation difficulties, and high travel costs and logistics in P.R. China. Early comparative studies of Carlin-type gold deposits between Nevada and P.R. China have been done during the past years (Cunningham and others, 1988; Dean and others, 1988; Ashley and others, 1991; Tu, G.Z., 1992; Mortensen and others, 1993; Wang, J. and Du, L.T., 1993; Liu, D.S. and others, 1994; and Li, Z.P. and Peters, 1996). These have demonstrated that there are comparative similarities between the deposits on the both continents and that the differences may be helpful in advancing our understanding of them.

In this report, *in*formation about Chinese Carlin-type gold deposits has been collected, translated and summarized into a database (appendix I), which is supported by Microsoft Access (97). This database currently consists of 114 records and 30 fields organized in six subsets. They are: (1) deposit name and reference; (2) geographical location (Province, County, latitude and longitude); (3) commodity information (size, ore and gangue mineral); (4) tectonic setting (regional trend, structural environment); (5) ore-control structures; and (6) host rock and alteration. Another 3 subsets are planned, they are: (7) geochemical data (analysis of rock and ore, trace elements, isotope, fluid inclusion, age data of rock and deposits); (8) graphic collection (regional, local, section, plan geological maps; photographs, sketch and chart of research result); and (9) production, reserves and resources (where possible). At the same time, part of these Chinese Carlin-type gold deposits have been input into MRDS (Mineral Resource Data System, see appendix-II), which is created by the U.S. Geological Survey. Translations of two Chinese language descriptions of the well studied and large Lannigou Carlin-type deposit in Guizhou Province (appendix 3-1) and the Proterozoic rock-hosted gold deposit in Hebei Province (Jidong area) (appendix 3-2) are contained in appendix III.

Chinese names and terms used in this paper are translated from Chinese symbols to pinyin, but do not contain the Chinese tones. References to Chinese authors also includes the author's initials to distinguish common last names. Chinese provinces have long and short names, so the two main areas of Chinese Carlin type deposits are referred to as a combination of the abbreviated short province names. The southwest area, Dian-Qian-Gui (Chen, Y.M., 1987), is located in the Yunnan (short name Dian), Guizhou (Qian), and Guangxi (Gui) Provinces. The central area, Qinling (or Chuan-Shan-Gan), is in the Sichuan (short name Chuan), Shannxi (Shan), Gansu (Gan) provinces. Eastern Hebei Province (shortened to Jidong), northeast China, respectively is a small and independent area that also contains several sedimentary rock-hosted gold deposits. The terms “Carlin-type” and “sedimentary rock-hosted” gold deposits are used interchangeably throughout this report and reflect the evolving nature of the classification of these deposits.

Figure 1. Photograph of manual mining in the Zimudang gold deposit, Guizhou province (Looking to southwest). Each miner trams about 25 kg of rock in double baskets. Total production is close to 300 tpd.

Figure 2. Photograph of manual mining in the Zimudang gold deposit, Guizhou province (Looking to southwest). Digging face in middle ground is the main shear zone.

Figure 3. Photograph of mechanized mining in the Hengxian gold deposit, Guangxi district (Looking to southwest). Blasting is commonly done at the toe of the bench, which collapses the brow. Mucking and tramming is by 20 tonne dump truck.

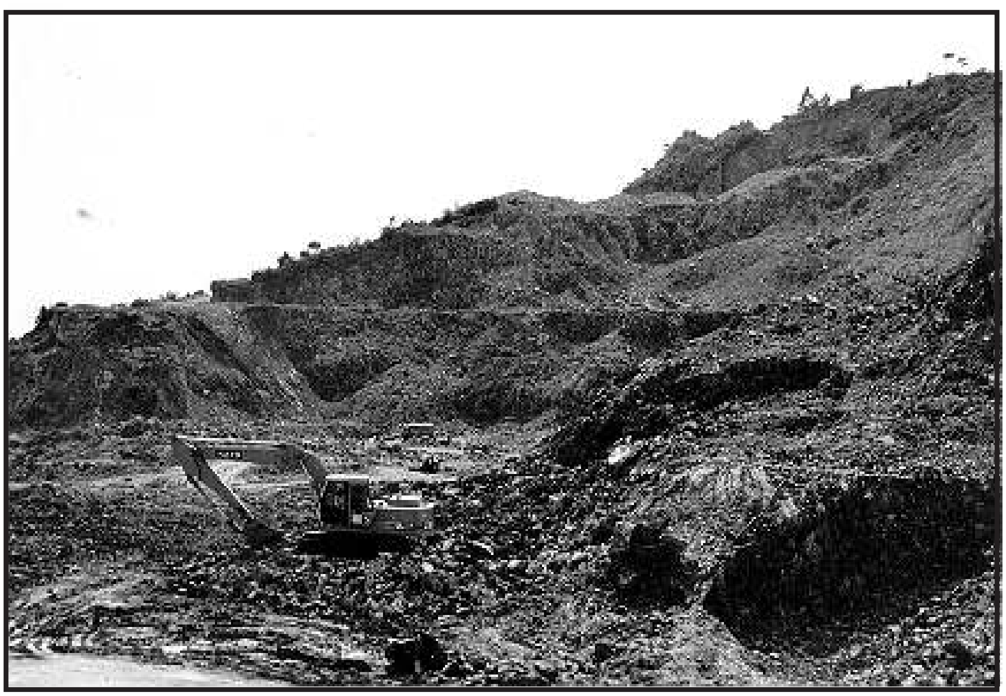

Figure 4. Photograph of mechanized mining in the Hengxian gold deposit, Guangxi District (Looking to southwest).