UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

THE NEWLY DISCOVERED SEDIMENTARY-ROCK HOSTED DISSEMINATED GOLD DEPOSITS IN THE PEOPLE'S REPUBLIC OF CHINA

by

Charles G. Cunningham, U.S. Geological Survey, 959 National Center, Reston, Virginia 22092

Roger P. Ashley, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025

I-Ming Chou, U.S. Geological Survey, 959 National Center, Reston, Virginia 22092

Huang Zushu (Zu-Shu Huang), Department of Regional Geology and Mineral Resources, Ministry of Geology and Mineral Resources, Xisi, Beijing, People's Republic of China

Wan Chaoyuan (Chao-Yuan Wan), Bureau of Geology and Mineral Resources of Guizhou Province, Beijing Road, Guiyang, Guizhou Province, People's Republic of China

Li Wenkang (Wen-Kang Li), Shenyang Institue of Geology and Mineral Resources, Shenyang, Liaoning Province, People's Republic of China

Open-File Report 88-220
1988

ABSTRACT

Five disseminated gold deposits recently discovered in southwestern Guizhou Province of the People's Republic of China are described here for the first time in Western literature. Exploration and drilling are in progress at the Yata, Getang, Sanchahe, Ceyang, and Banqi deposits. The sizes of the deposits are as yet undetermined, but they contain significant reserves at average grades of 4 to 5 grams of gold per tonne. Features of the deposits are similar to those of some major sedimentary-rock hosted precious metal deposits in Nevada. Gold is less than one micrometer in diameter and is disseminated in Permian and Triassic silty carbonate and black shale host rocks. Arsenic, antimony, mercury, and thallium were introduced along with silica and pyrite. Preliminary fluid inclusion homogenization temperatures range from 120° to 240°C, and associated salinities are less than 5 wt percent NaCl equivalent. Alteration minerals are predominantly hydrothermal illite and kaolinite.

The deposits are structurally and stratigraphically controlled and are located near the buried southwestern margin of the Precambrian Yangtze craton in the vicinity of the transition from platform carbonates to deep water shales and turbidites at the continental slope. Gentle folding occurred during the Yanshanian orogeny, 190 to 65 Ma, and the deposits are in anticlines that often expose Permian rocks surrounded by Triassic rocks. The deposits differ from similar types in the United States in that they are apparently smaller, have no known spatially associated igneous rocks, and are hosted in younger rocks.

INTRODUCTION AND PREVIOUS STUDIES

Sedimentary-rock hosted disseminated gold deposits (Carlin-type deposits) have recently been recognized in the People's Republic of China. Five deposits recently discovered in Guizhou Province (Fig. 1)--the Yata, Getang, Sanchahe, Ceyang, and Banqi deposits--are described here for the first time in Western literature. The deposits have geologic features and geochemical signatures that are remarkably similar to those of sedimentary-rock hosted precious-metal deposits in the United States. The sizes of the deposits are as yet undetermined, but they each contain significant reserves at average grades of 4 to 5 grams of gold per tonne. Exploration and drilling are in progress at all of the deposits, and other areas where the geologic setting and geochemical anomalies are similar are being tested.

The deposits are located in a relatively inaccessible region in the southern part of the People's Republic of China. We visited four of the five deposits described in this report in September 1986 as part of a cooperative study between the U.S. Geological Survey and the Ministry of Geology and Mineral Resources of the People's Republic of China. Transportation and logistical support for site visits were provided by the Bureau of Geology and Mineral Resources of Guizhou Province, the organization primarily responsible for mineral exploration in the region.

Very little has been published about sedimentary-rock hosted disseminated gold deposits in the People's Republic of China (Li et al., 1986). The Chinese literature sometimes refers to them as "underground hydrothermal (brine) leaching gold deposits" (Cai and Li, 1986). Analytical information from samples collected by us in the course of this study is available in Dean et al., (1988).

GEOLOGIC AND TECTONIC SETTINGS

The sedimentary-rock hosted disseminated gold deposits in the People's Republic of China were first recognized about 1980. Most are located near the southern edge of the Precambrian Yangtze craton, one of three Precambrian cratons and adjoining accretionary fold belts that underlie most of the country (Zhang and others, 1984; Xiong and Coney, 1985). Most of Guizhou Province is underlain by the Yangtze craton, which is composed of Proterozoic crystalline rocks overlain by Paleozoic and Lower to Middle Triassic marine deposits and Upper Triassic terrestrial deposits (Xiong and Coney, 1985; Bureau of Geology and Mineral Resources of Guizhou Province, 1986).

Devonian to Triassic shallow marine carbonate rocks were deposited on a broad cratonic platform near the edge of the Yangtze craton (Fig. 2). Reef facies mark the edge of the craton, and turbidites intercalated with argillaceous rocks were deposited on the continental slope and in deeper water environments. The area was uplifted during Late-Triassic time and was covered by widespread terrestrial deposits, including coal beds.

Figure 1.--Location of the newly discovered sedimentary-rock hosted disseminated gold deposits in Guizhou Province and other reported occurrences (solid circles) in the People's Republic of China. Province names and principal cities (stars) are given for reference.

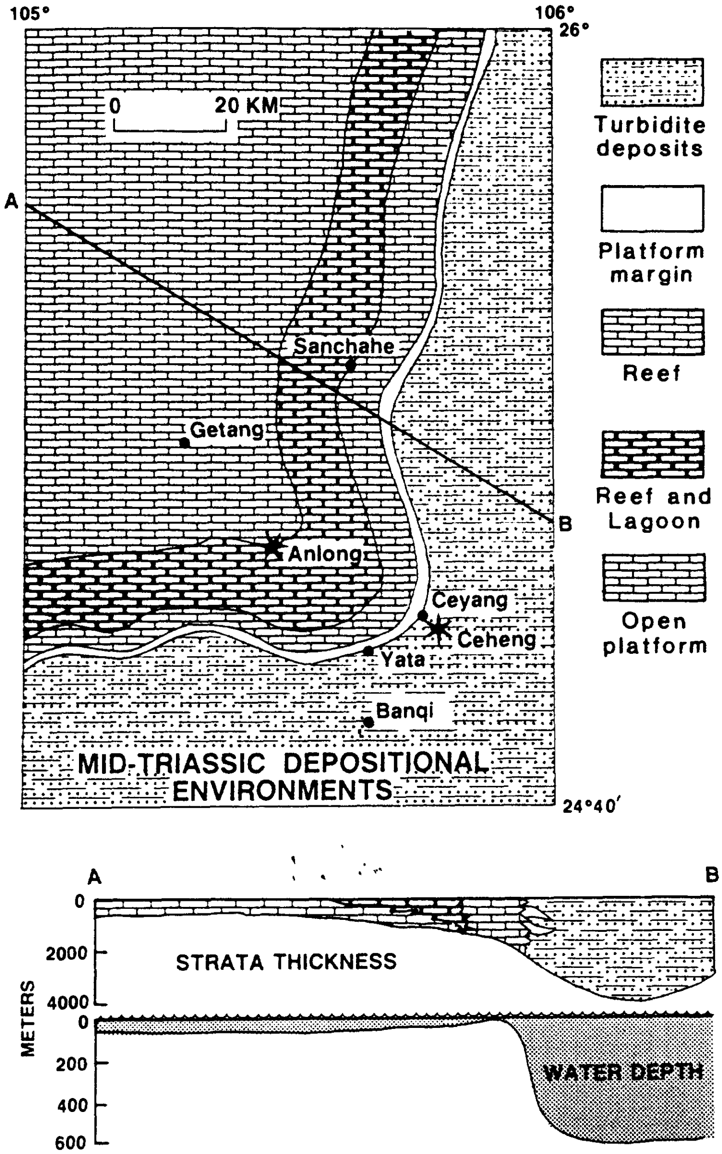

Figure 2.--Middle-Triassic depositional environments for rocks that host disseminated gold deposits in Guizhou Province. Strata thickness and interpreted water depth, indicating the position of the buried margin of the Precambrian Yangtze craton, are shown. The locations of the newly discovered deposits (solid circles) and principal towns (stars) are shown.

The rocks were pervasively folded and faulted during the Yanshanian orogeny, 190 to 65 Ma. Gentle to locally moderately tight folds, sometimes associated with high-angle faults, trend generally east-west in the vicinity of the disseminated gold deposits. Most of the rocks at the surface in southwestern Guizhou Province are Triassic in age. Permian rocks generally crop out in the cores of anticlines and in partly exposed reefs that were topographic highs during the Triassic (Bureau of Geology and Mineral Resources of Guizhou Province, 1986). No igneous rocks are exposed in the immediate vicinity of the gold deposits. Permian basalts crop out 50 to 100 km northwest of the area of the deposits and a small body of Yanshanian alkaline ultramafic rock crops out 10 km east of the Sanchahe deposit.

DESCRIPTION OF DEPOSITS

Yata

The Yata gold deposit is located 16 km southwest of the town of Ceheng (Fig. 2). Access to the mine is by trail from the village of Yata. The deposit was originally mined for realgar, and many old tunnels are present. A few exploration samples from the old workings gave analyses of 1 to 3 grams of gold per tonne, with a maxium of 13.4 grams per tonne. The ore host is a dark gray to black thin-layered argillaceous limestone interlayered with shale, arkose, and fine-grained turbidite sandstone of the Middle Triassic Xinyuan Formation (Fig. 3). The main structure of the area is an east-west trending anticline with subsidiary anticlines, synclines, and east-west trending faults subparallel to the trend of fold axes (Fig. 3).

The Yata deposit contains nine known orebodies with average grades as high as 5 grams per tonne; the deposit contains a total of approximately 5 metric tonnes of gold. The orebodies are localized by the steeply dipping east-trending faults, and gold is disseminated into the wall rocks. The main ore-bearing zone is more than 1,000 m long and several tens of meters wide and appears to be directly associated with an east-trending fault. The ore occurs preferentially in the arkosic and shale-rich horizons and is associated with intensely silicified rocks.

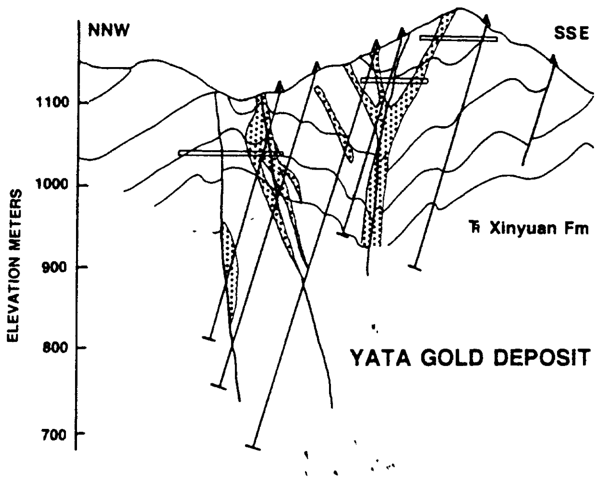

Figure 3.--Geologic cross section of the Yata gold deposit, Guizhou Province, People's Republic of China. The host rock is folded Triassic Xinyuan Formation. Gold ore is shown patterned. Light lines show orientation of bedding, and heavy lines are faults. Mine tunnels are shown as horizontal lines. Drill holes are also shown.

Pyrite and realgar are the most common sulfides in the deposit, although arsenopyrite, chalcopyrite, marcasite, stibnite, and sphalerite are present. The highest gold grades are associated with the assemblage pyrite-arsenopyrite-marcasite-ankerite. Lesser amounts of gold are associated with the pyrite-arsenopyrite-marcasite assemblage, and a cross cutting pyrite-realgar-stibnite-quartz assemblage does not contain gold. The gold particles are generally about a micrometer in diameter and scanning electron microscopy indicates they appear to be concentrated with sulfides and clay minerals. Gold is related to early silicification and locally forms overgrowths on arsenic-bearing pyrite; gold deposition was followed by the formation of stibnite. The deposit is surrounded by a mercury geochemical anomaly. Homogenization temperatures for fluid inclusions in quartz are 150 to 240°C, and salinities are as much as 5 wt percent NaCl-equivalent.

Getang

The Getang gold deposit is located 27 km northwest of Anlong (Fig. 2), the largest town in the area. It is presently being drilled on a 40 m grid to evaluate its potential for production. Sedimentary rocks exposed in the area are of Permian and Early Triassic age. The Permian Maokou Formation is a massive gray limestone with a karst unconformity at the top. The Maokou Formation is overlain by the Upper Permian Longtan Formation, an argillaceous limestone that contains coal layers, silicified shale, and clastic rocks near the top.

The deposit is located on the eastern limb of the Getang dome, a northwest-trending anticline about 50 km long. The Permian rocks are exposed in an inlier at the center of the dome. The rocks in the vicinity of the deposit dip about 10° northeast and are cut by high-angle reverse faults with small displacements.

Gold is concentrated along a 3-to 15-m-thick breccia horizon at the base of the Longtan Formation. Regionally, this horizon is characterized by karst development, but, in this locality, it may mark a superimposed bedding- plane thrust fault. Lenticular orebodies crop out discontinuously along the breccia horizon over a distance of 1,000 m and consist of silicified, argillaceous, carbonate breccia having a chalcedonic matrix. The ore grades from 2 to 5 grams of gold per tonne and locally contains as much as 50 grams per tonne. Gold content in the ore increases as the degree of silicification increases.

Pyrite, stibnite, marcasite, arsenopyrite, realgar, and cinnabar are spatially associated with gold at Getang. Gangue minerals include chalcedonic quartz, illite, calcite, dolomite, and minor fluorite and barite. Much of the deposit is oxidized, and limonite is common. Native gold occurs principally as grains less than 0.5 micrometers in diameter; locally, grains up to 3 micrometers are present. Gold is disseminated within the host rocks and also occurs with limonite in oxidized rocks. The grade of the ore increases from 2 to 3 grams of gold per tonne in unoxidized ore to 4 to 5 grams per tonne in limonite-bearing oxidized ore. A few preliminary fluid inclusion homogenization temperatures in quartz average approximately 120°C. Jasperoid and silicified limestone containing pyrite and stibnite overlie the gold deposit. Geochemical anomalies of arsenic and mercury are present.

Sanchahe

The Sanchahe gold deposit is located 45 km northeast of Anlong (Fig. 2). Old mercury and arsenic mines are present in the area, and the Sanchahe deposit was discovered because assays of samples collected during a mercury reconnaissance program contained about 3 grams of gold per tonne. The deposit is hosted in sandy shales containing thin coal beds of the Upper Permian Longtan Formation and overlying argillaceous carbonates and arkosic shales of the Permian Changxing and Dalong Formations, and the Lower Triassic Yelang Formation (Fig. 4).

The Sanchahe deposit is located along the crest of a 40-km-long northwest-trending anticline that exposes Permian strata in the center. Reverse faults trend parallel to the crest of the dome and have influenced the location of orebodies.

Current drilling has defined several lenticular orebodies 65 to 200 m long and 6 to 15 m thick that grade from 3.9 to 5.2 grams of gold per tonne. Wall rock alteration and mineralization, principally in the vicinity of the faults, is characterized by the introduction of quartz, pyrite, arsenopyrite, and calcite followed by realgar, cinnabar, marcasite plus minor barite, fluorite, and stibnite. The ore contains as much as 100 ppm thallium. This deposit is the only one containing a known thallium anomaly. Fine-grained disseminated gold is closely associated with pyrite, arsenopyrite, and quartz. Assays of mineral separates indicate that some pyrite contains gold. Oxidation has caused some enrichment of gold at or near the ground surface.

Ceyang

The Ceyang deposit is located 7 km west of the town of Ceheng (Fig. 2), where the deposit crops out along the Guizhou-Guangxi highway. This newly discovered deposit, which is marked by a gold and arsenic geochemical anomaly, is hosted by arkosic shales of the Middle Triassic Xinyuan Formation that overlie Permian argillaceous carbonates.

The Ceyang gold deposit is at the southern end of the 30-km-long Lugong anticline. The axis of the anticline trends north-south, approximately parallel to the margin of the Yangtze craton and to the strike of the facies changes (Fig. 2). The anticline exposes Permian rocks along the crest. Large northeast-trending reverse faults are closely related to the distribution of the gold. Northwest-trending strike-slip faults commonly displace the northeast-trending faults.

The orebodies are in a silicified and pyritized zone up to 2,000 m long at the intersection of arkosic shales of the Xinyuan Formation and the northeast-trending faults. Six orebodies identified to date are 35 to 130 m long and 1 to 3 m thick and generally contain 3 to 5 grams of gold per tonne, with a maximum grade of 7 grams per tonne. Disseminated gold grains are generally about a micrometer in diameter, but optical microscopy shows that larger ones are present and appear to be spatially related to clay minerals, pyrite, arsenopyrite, and chalcopyrite.

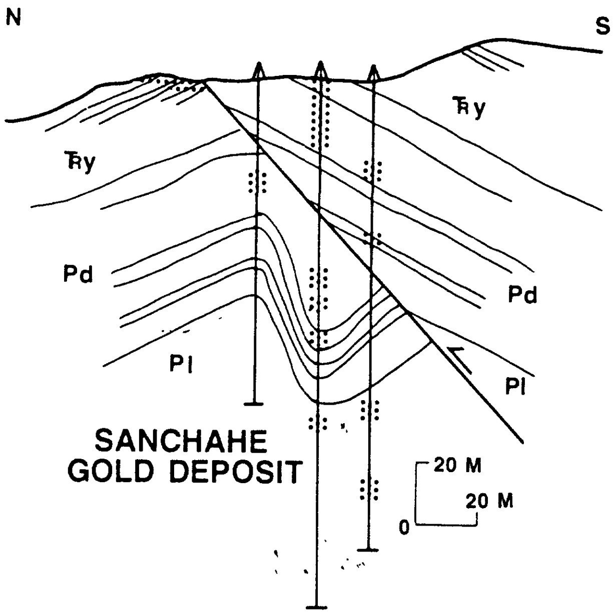

Figure 4.--Geologic cross section of the Sanchahe gold deposit, Guizhou Province, People's Republic of China. The host rock is folded and faulted Permian Longtan Formation (Pl), Permian Dalong Formation (Pd), and Triassic Yelang Formation (Ꞧy). Light lines show the orientation of bedding, and the heavy line is a thrust fault. Drill holes are shown. The solid circles along drill holes are ore zones.

Banqi

The Banqi deposit is located about 10 km south of the Yata deposit and was not visited by the United States-Chinese team because of difficulty of access. It is reportedly similar to the Getang deposit and contains several grams of gold per tonne.

The deposit is hosted in the Middle Triassic Xinyuan Formation and is located along the southern edge of a small (15 km long) east-west-trending dome that has Permian Houziguan limestone exposed in the center (Bureau of Geology and Mineral Resources of Guizhou Province, 1986). The gold orebodies are in a carbonate breccia along a fault that is parallel to the axis of the dome.

Other deposits

The Ertaizi gold deposit is a minor prospect located southeast of Xían City in Shaanxi Province (Fig. 1), near the town of Zhenan. The deposit is hosted in Devonian carbonates and is believed to be generally similar to the Guizhou deposits. Fluid inclusions have homogenization temperatures of 110° to 280°C and high salinities (Liu and Geng, 1985). Feng (1982), Shao et al. (1982), and Xu et al. (1982) described small deposits in Shaanxi Province where the ore is hosted by Devonian carbonates and calcareous siltstones; they may be have been referring to the Ertaizi deposit.

Information on other "Carlin-type" deposits, such as the Lijiagou and Ertaizi deposits in Shaanxi Province, the Shixia deposit in Hunan Province, and a new discovery in Hubei Province, as well as on the Miaolong and Banqi deposits in Guizhou Province, was given by Liu and Geng (1985). Discovery of a probable "Carlin-type" gold deposit in western Guangxi Province was reported in the People's Daily in February 1987 (C. A. Kuehn, Pennsylvania State University, written communication, 1987).

DISCUSSION

The newly discovered sedimentary-rock hosted disseminated gold deposits in the People's Republic of China have many features in common with the better known "Carlin-type" deposits in the Western United States. The Chinese deposits discovered to date contain a few metric tons of gold at a grade of 4 to 5 grams of gold per tonne whereas the median "Carlin-type" deposit of the Western United States contains about 13 metric tonnes of gold at a grade of 2.5 grams per tonne (Bagby et al., 1986). In both the Chinese and United States deposits, the distribution of gold is structurally controlled and is disseminated into the wall rocks. The host rocks of the Chinese deposits are generally younger (Permian and Triassic) than those of the United States deposits (mostly lower to middle Paleozoic), but the lithologies are similar. Gold in both sets of deposits is generally less than one micrometer in diameter, has a high ratio of gold to silver, and is associated with arsenic, antimony, mercury, and thallium minerals (Dean et al., 1988). Pervasively silicified rock, jasperoid, decarbonated limestone, argillically altered rock, and introduced pyrite also seem to be common denominators. Fluid inclusion data from the Chinese deposits, exhibiting filling temperatures of 120° to 240°C and salinities less than 5 wt percent NaCl equivalent (CO_2 contents are not known) are comparable to those reported for the United States deposits (Tooker, 1985; Radtke, 1985; Northrop et al., 1987), although the inclusions in some Chinese deposits may have significantly higher salinities (Liu and Geng, 1985).

Both Chinese and United States deposits are spatially located near the buried edge of a Precambrian craton. The newly discovered deposits in Guizhou Province are associated with antiforms along the edge of the Yangtze craton. Four out of five deposits (Yata is the exception) are associated with inliers in the Triassic rocks that expose Permian strata. Although many of these antiforms are structural, some are Permian structural highs onlapped by Triassic rocks, and the latter may have acted as loci of folding during later compression. Similarly, some deposits in the United States, such as Carlin, are spatially associated with windows eroded through antiforms in the upper plate of the Roberts Mountains thrust.

The position of the edge of the Yangtze craton had a significant effect on the depositional environment of sedimentary rocks throughout the late Paleozoic and early Mesozoic. Similarly, the position of the North American craton in the Western United States had a profound influence on depositional environments of lower Paleozoic sedimentary rocks. Many of the major sedimentary-rock hosted disseminated gold deposits of the Western United States are aligned along the edge of the buried Precambrian craton (Cunningham, 1988). The host rocks of both sets of deposits have undergone similar tectonic histories, although at different times. The Yanshanian orogeny was active from 190 Ma to 65 Ma and was marked by a compressive phase followed by an extensional phase. The anticlines and reverse faults that host much of the Chinese gold ore formed during the compressive phase. The Chinese deposits are not well dated, and the only preliminary date available is a 100-Ma age on galena from the Yata deposit suggesting that the Chinese deposits formed during the extensional phase of the Yanshanian orogeny. A somewhat similar history of compression and extension, albeit over a different time span, is recorded for the rocks of east-central Nevada. These gold deposits appear to have formed in the middle-to-late Tertiary during extensional tectonism. Possibly in both cases, extensional movement in conjunction with the buttressing effect of the Precambrian craton localized crustal rifting that produced the thermal systems leading to the formation of the gold deposits.

The Chinese deposits are currently being actively explored and developed; at least some exploration is concentrated in areas containing known deposits of antimony, mercury, and arsenic and in the vicinity of the buried edge of the Precambrian craton. Some of this area is especially favorable for disseminated gold deposits because of its relationship to recent continental extension, high heat flow, hot-spring activity, bimodal volcanism and favorable host rocks (Casaceli and Gemuts, 1985). The new deposits that are likely to be discovered could have a significant impact on the Chinese economy when they are put into production.

ACKNOWLEDGMENTS

We appreciate the help of our colleagues in the Chinese and U.S. mining industries who have led field trips, provided deposit maps and samples, and shared their data and ideas with us. They include Roger Banghart, Chen Junhua, Odin Christensen, Dai Guohou, Charlie Ekburg, Han Zhijun, John Hill, Hu Qengcheng, Gale Knutsen, Liao Changhai, Bradford Mills, Richard Nanna, Richard Reid, K. Wing Tsang, Ed Wells, and Zhang Lingsan. Members of the U.S. Geological Survey, chiefly William Bagby, Byron Berger, and James Rytuba, have similarly provided thoughtful advice both in the field and in the office.

REFERENCES

Bagby, W. C., Menzie, W. D., Mosier, D. L., and Singer, D. A., 1986, Grade and tonnage model of carbonate-hosted Au-Ag in Cox, D. P., and Singer, D. A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.

Bureau of Geology and Mineral Resources of Guizhou Province, 1986, Geological map of Guizhou Province, People's Republic of China: China Geological Map Printing House, scale 1:500,000.

Cai, Changjin, and Li, Zhixiang, 1986, The geological characters of occurrence of gold minerals in China: China National Gold Corporation, unpublished manuscript, March 1986, 34 p.

Casaceli, R. J., and Gemuts, Ilmars, 1985, Precious metal deposits related to continental extension [abs.]: Global tectonics and metallogeny, v.3, no.1, part 3, p.7-8; Abstracts of papers presented at the Santa Fe workshop, New Mexico, September 1985, Commission on Tectonics of Ore Deposits of the International Association on the Genesis of Ore Deposits.

Cunningham, C. G., 1988, The relationship between some disseminated gold deposits, the western edge of the Precambrian craton and paleothermal anomalies in Nevada, in Schafer, R., Cooper, J., and Vikre, P. eds., Bulk minable precious metal deposits of the western United States Symposium Volume, Geological Society of Nevada, in press.

Dean, W. E., Bostick, N. H., Bartel, A. J., Brandt, E. L., Davis, T. A., Doughten, M, Gent, C. A., Jaunaraja, S. R., Libby, B., Malcolm, M. J., Robb, E. C., Taggart, J. E., Threlkeld, C. N., Vuletich, A. K., Cunningham, C. G., Ashley, R. P., and Chou, I-M, 1988, Data on the geochemistry and thermal maturation of sedimentary-rock hosted disseminated gold deposits and associated rocks, Southwestern Guizhou Province, People's Republic of China: U.S. Geological Survey Open-File Report 88-271, 22p.

Feng, Shuzhuang, 1982, Characteristics of ore textures in a "Carlin type" gold deposit in Shaanxi: Geology and Prospecting, p. 14-20.

Li, Wenkang, Zheng, Qiqian, and Liu, Juesheng, 1986, The geological and mineralization characteristics of impregnated gold deposits in southwestern Guizhou, China: Bulletin of the Shenyang Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences, no. 13, p. 135-150.

Liu, Dongsheng and Geng, Wenhui, 1985, On the mineral association and mineralization conditions of the Carlin-type gold deposits in China: Geochimica, v. 3, p. 277-282.

Northrop, H. R., Rye, R. O., Landis, G. P., and Lustwerk, R., 1987, Sediment-hosted disseminated gold mineralization at Jerritt Canyon, Nevada, V, Stable isotope geochemistry and a model of ore deposition: Geological Society of America Abstracts with Programs, 1987 Annual Meeting, vol. 19, no. 7, p. 791.

Radtke, A. S., 1985, Geology of the Carlin gold deposit: U.S. Geological Survey Professional Paper 1267, 124 p.

Shao, Jielian, Xu, Guofeng, Feng, Shuzhuang, Lu, Ruiying, and Mei, Jianming, 1982, On the study of pyrite from a certain "Carlin type" gold deposit in Shaanxi, China: Acta Petrologica Mineralogica et Analytica v. 1, no. 2, p. 25-35 [in Chinese with an English abstract].

Tooker, E. W., ed., 1985, Geologic characteristics of sediment-and volcanic-hosted gold deposits-- Search for an occurrence model: U.S. Geological Survey Bulletin 1646, 150 p.

Xiong, Ji, and Coney, P. J., 1985, Accreted terranes of China, in Howell, D. G., ed., Tectonostratigraphic terranes of the Circum-Pacific: Council for Energy and Mineral Resources, Earth Science Series, no. 1., Houston, Texas, p. 349-361.

Xu, Guofeng, Shao, Jielian, and Feng, Shuzhuang, et al. 1982, On the mineralogical study from a "Carlin type" gold deposit in Shaanxi, China: Earth Science Journal of Wuhan College of Geology, v. 18, no. 3, p. 211-221 [in Chinese with an English abstract].

Zhang, Z. M., Liou, J. G., and Coleman, R. G., 1984, An outline of the plate tectonics of China: Geological Society of America Bulletin, v. 95, no. 3, p. 295-312.