CHAPTER 3

Geology and Geochemistry of Sedimentary Rock-Hosted Au Deposits of the Dian-Qian-Gui Area, Guizhou, and Yunnan Provinces, and Guangxi District, P.R. China

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Open-File Report: 02–131

2002

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U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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Abstract

Sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area in southwest China are present in Paleozoic and early Mesozoic sedimentary rocks along the southwest margin of the Yangtze Precambrian craton. These deposits are Carlin-type Au deposits and are spatially associated, on a regional scale, with deposits of coal, Sb, Barite, and Hg. Most sedimentary rock-hosted Au deposits are stratabound and/or structurally controlled, and are disseminated deposits commonly associated with structural domes. Typical characteristics include impure carbonate rock or calcareous and carbonaceous host rock that contains disseminated pyrite, marcasite, and arsenopyrite—usually with micron-sized Au, commonly in As-rich rims and disseminations. Associated with these sulfide minerals are paragenetically late realgar, orpiment, stibnite, and Hg-minerals. Minor base-metal sulfide minerals, such as galena, sphalerite, chalcopyrite, and boulangerite also are present. The rocks locally are silicified and altered to sericite-clay (illite). —Geochemical signatures are characterized by elevated values of As, Sb, Hg, Tl, and Ba.

General lack of igneous rocks in the Dian-Qian-Gui area implies non pluton-related ore forming processes. Some deposits contain characteristics suggest that metal sources may have originated in carbonaceous parts of the sedimentary pile or other sedimentary or volcanic horizons. This genetic process may be associated with the process that formed and mobilized petroleum and Hg and may also be related to As-, Au, and Tl-bearing coal horizons. Many deposits contain textures and features that indicate a strong structural control by tectonic domes or shear zones and suggest syndeformational ore deposition, possibly related to the Youjiang rift fault system. Several sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area also are of the red earth-type and have been concentrated and enhanced by the processes of deep weathering.

摘 要

中国西南滇黔桂地区沉积岩型金矿产于扬子前寒武纪克拉通西南缘的古生代和早中生代沉积岩中。这些金矿床为卡林型金矿床。在区域上，这些金矿床与煤矿、锑矿、重晶石矿及汞矿有密切的空间关系。大多数沉积岩型金矿床为层控或受构造控制的浸染状矿床，通常与构造穹隆有关。这类矿床典型特征是产于不纯的碳酸盐或钙质和碳质岩石中。这些沉积岩含有浸染状黄铁矿、白铁矿和毒砂--微粒金通常产于高砷边。与这些硫化物伴生的是晚期的雄黄、雌黄、辉锑矿和汞矿物，并有少量的贱金属硫化物如方铅矿、闪锌矿、黄铜矿和块硫锑铅矿。蚀变主要为硅化和绢云母-粘土（尹利石）化。地球化学方面以As、Sb、Hg、Tl和Ba的含量升高为特征。

滇黔桂地区普遍缺失火成岩，表明该区的成矿作用与侵入体无关。一此矿床的特征表明成矿的金属来源于沉积岩系的碳质岩或其他沉积岩或火山岩层。该区的成矿组合可能是形成和运移石油及汞的过程之结果，煤系地层中的As、Au和Tl也可能与这种组合有关。另一些金矿床的结构和明显受构造穹隆或剪切带控制的特征，表明同变形的矿石沉淀可能与右江裂谷系有关。该区几个沉积岩金矿床也属于红土型矿床，由强烈的风化作用而富集。

INTRODUCTION

The Dian-Qian-Gui area is located in southwest China in the Provinces of Yunnan (Dian), Guizhou (Qian) and the District of Guangxi (Gui) (Chen, Y.M., 1987) (fig. 3-1). The area is a mountainous, high plateau terrain that contains central elevations between 1,000 and 2,000 m. The Dian-Qian-Gui area contains an approximately 55,000–m-sequence of sedimentary rocks that range in age from Precambrian to Tertiary. Guizhou Province means the kingdom of sedimentary rocks. The region contains many deposits of coal, Sb, Barite, and Hg, as well as a large number of sedimentary rock-hosted Au deposits of the Carlin-type (Cunningham and others, 1988; Lu, G.Q. and others, 1992, Huang, Y.I, 1993; Huang, G.S. and Du, 1993; Cun, G., 1995).

Characteristics of most sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area are similar and included stratabound or structurally controlled disseminated deposits that are commonly associated with structural domes (Cunningham and others, 1988; Liu, D.S., 1992; Liu, D.S. and others, 1991, 1994; He, L.X., and others, 1993; Wang, K.R. and others, 1994; Li, Z.P, and Peters, 1998; Hu, R.Z. and others, 2001). These domes have geometric and lithologic similarities to the tectonic windows that influence distribution of Carlin-type deposits in Nevada (see also, Bagby and Berger, 1985; Berger and Bagby, 1991; Arehart, 1996; Hofstra and Cline, 2000). Description and study of the Chinese sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area is intended to shed light on the control and metallogenesis of these deposits in both countries.

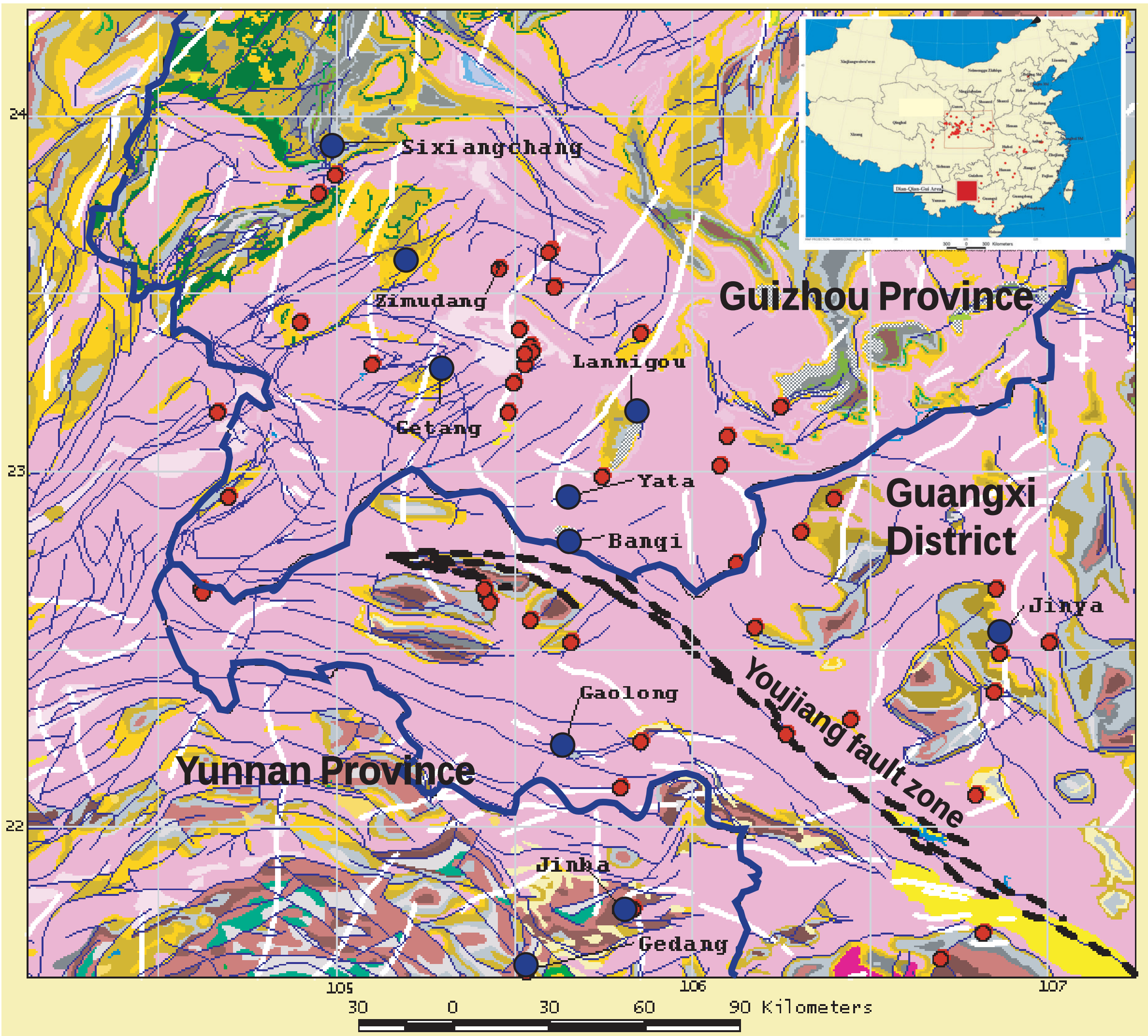

Figure 3-1A. Geologic map of the Dian-Qian-Gui area, showing distribution of sedimentary rock-hosted Au deposits (red circles). Large blue circles with labels and those that are discussed in the text. Map shows Triassic basin composed mainly of turbiditic sandstone and shale with underlying domes of carbonate rock exposed (yellows, greens and browns). Red square in inset shows location of Dian-Qian-Gui area. Legend layout, style, and geological map unit classification scheme is adapted from the Geological Map of China (Cheng, 1990). See Cheng (1990) and Wang (1990). For additional detail, see fig. 3-1B for generalized geologic legend.

EXPLANATION

STRATIGRAPHY

Quaternary

Q — Alluvium, mud, silt, loess; pebble beds in west Qinling area

Neogene

N — Mainly continental clastics, volcanics in Jinghong area

Eogene

E — Clastic rocks with volcanics in eastern Yunnan

Cretaceous

K, K2, K1 — Mainly continental and marine clastics with minor volcanics in western Qinling area

Jurassic

J, J3, J2, J1 — Continental clastic rocks with intrusives in western Qinling area

T-J — Incorporated beds; undivided

Triassic

T, T3, T2, T1 — Carbonates interbedded with sandstone and shale, volcanics in Zhongdian and Baoshan areas

P-T — Incorporated beds; undivided

Permian

P, P2, P1 — Continental clastic rocks interbedded with coal in Qinling area, volcanics in north Yunnan

MP-P — Incorporated beds; undivided

Mississipian-Pennsylvanian

MP, MP3, MP2, MP1 — Continental clastics; limestone interbedded with volcanics in Weixi area

D-MP — Incorporated beds; undivided

Devonian

D, D3, D2, D1 — Marine and continental clastics, volcanics in Jinghong area

S-D — Incorporated beds; undivided

Silurian

S, S3, S2, S1 — Marine clastics & mixed carbonate rocks in Yangtze region, vocanic rocks in west Qinling area

O-S — Incorporated beds; undivided

Ordovician

O, O3, O2, O1 — Continental carbonate and clastic rocks, shallow marine volcanics west Qinling

Cambrian

C — Clastic and carbonate rocks in Yangtze region

Precambrian

pC, pC3, pC2, pC1 — Undivided

INTRUSIVE ROCKS

1. Granitoids

- gd — granodiorite
- g — granite
- xo — quartz-syenite (porphyry)
- eo — quartz-monzonite (porphyry)
- do — quartz-diorite (porphyry)

2. Diorites

- d — diorite

3. Mafic rocks

- n — gabbro
- bm — diabase

4. Ultramafic rocks

- s — peridotite
- pi — pyroxenite (porphyrite)

5. Alkanline rocks

- k — alkaline rocks
- b — Basalts
- x — syenite (porphyry)

VOLCANIC ROCKS

- a — Andesites

AGE SUBDIVISIONS

Age subdivisions appear as suffixes to formation alphanumeric codes:

5 = Yanshanian
5-3 = Late Yanshanian
5-2 = Early Yanshanian
5-1 = Indosinian
4 = Variscan
3 = Caledonian
3-2 = Late Caledonian
3-1 = Early Caledonian

Figure 3-1B: Legend for the geological map of the Dian-Qian-Gui area, Figure 3-*1A*. Legend layout, style, and geological map unit classification scheme is adopted from the Geological Map of China (Cheng, 1990). See Cheng (1990) and Wang (1990) for additional details.

Many characteristics of the sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area are similar to those in Nevada (Liu, D.S. and Geng, W.H., 1985; Ashley and others, 1991; Liu, B.G. and Yeap, 1992; Tu, G.Z, 1992, 1994; Li, Z.P., and Peters, 1996, 1998). These common characteristics include impure carbonate rock or calcareous and carbonaceous host rock that contains disseminated arsenical pyrite, marcasite, and arsenopyrite. These minerals usually contain micron-sized Au, commonly in As-rich rims and disseminations of pyrite. Associated with these sulfide minerals are paragenetically late realgar, orpiment, stibnite, and Hg-minerals. Minor base-metal sulfide minerals, such as galena, sphalerite, chalcopyrite, and boulangerite also are present in some deposits. Hydrothermal alteration mainly consists of silicification and sericite-clay (illite) alteration (Zheng, Z.G., 1984; Shao, J.L., 1989; Li, W.K. and others, 1986, 1989; Ashley and others, 1991; Mao, S.H., 1991; Togashi, 1992; Wang, K.R., and Zhou, Y.Q., 1992; Wang, K.R. an others, 1994; Liu, D.S., and others, 1994; Luo, X.H., 1994, 1996). These mineralogical assemblages, textures and paragenetic sequences also are similar to those found in Carlin-type Au deposits in Nevada (see also, Hausen and Kerr, 1968; Geng, W.H., 1985; Bakken, 1990; Gu, X.X., 1996; Ferdock and others, 1997; Fleet and Mumin, 1997; Vikre and others, 1997).

Geochemical signatures of the sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area are characterized by elevated values of As, Sb, Hg, Tl, and Ba (Cen, Y.M., 1987; Dean and others, 1988; Wang, X.C., 1992). These elements also are the pathfinder elements for most Carlin-type deposits in Nevada (Hill and others, 1986; Percival and others, 1988; Li and Peters, 1998; Hofstra and Cline, 2000). The association of the sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area with deposits or occurrences of Ba, Sb, and Hg is strong and this association has led to theories of the genesis of the Au deposits. Many small-size Hg deposits and occurrences in the Dian-Qian-Gui area are thought to be related to processes that have concentrated oil and gas in the abundant domal anticlines in the area (He, L.X., and Zheng, R.L., 1992). A number of significant Sb deposits in the Dian-Qian-Gui area are part of the South China Sb belt that includes many sedimentary rock-hosted Au belts (Wu, J.D. and others, 1992). These associations and the uniform characteristics of the sedimentary rock-hosted Au deposits are compatible with a regional-scale metallogenic and tectono-thermal event that may have been responsible for the formation of a number of related deposit types.

Regional-scale and district-scale ore controls and metallogenic setting of the sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area are defined by individual deposit characteristics. General lack of igneous rocks in the area implies that non pluton-related ore forming processes must be considered as possible genetic mechanisms to form the deposits (Li, W.K., and others, 1989; Mai, C. R., 1989; Tao, C.G., 1990; Liu, K.Y., 1991; Deng, X.E., 1993; Tan, Y.J., 1994; Gao, Z.B. and others, 1996; He, M.Y, 1996; see also, Ilchick and Barton, 1997). Some deposits contain characteristics that suggest metal sources in the sedimentary pile, particularly associated with carbonaceous material. Other deposits contain textures and features that indicate a strong structural control by tectonic domes or shear zones and lead to genetic theories of syndeformational deposition. Several sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area are of the red earth-type and have been concentrated and enhanced by the processes of deep weathering and laterization.

This chapter results from investigations in the Qinling fold belt area as part of a joint collaborative agreement between the U.S. Geological Survey and the Tianjin Geological Academy to study and compare sedimentary rock-hosted Au deposits in the P.R. China and in Nevada. The agreement calls for joint field visitations and compilations and has resulted in research and preliminary classification of sedimentary rock-hosted and Carlin-type Au deposits (Chapters 1 and 2) and descriptions of deposits in the Dian-Qian-Gui (this Chapter 3) and Qinling fold belt (Chapter 4), and the Middle-Lower Yangtze River areas (Chapter 5) P.R. China. An earlier project report is contained in Li, Z.P. and Peters (1998) with an interactive Web-based database on sedimentary rock-hosted Au deposits at [http://geopubs.wr.usgs.gov/open-file/of98-466/].

The chapter contains descriptions and results of field and laboratory studies of the Au deposits visited in 1997 and 2000. In addition, information from a number of prominent sedimentary rock-hosted Au deposits in Guizhou Province is from compilation of literature (see also, Li, Z.P., and Peters, 1998). For more detailed discussion of metallogenesis and deposit classification see Chapters 1 and 2.

Stratigraphic nomenclature used in this chapter conforms, in most cases to that proposed by the Ministry of Geology and Mineral Resources (1985) and updated by the Committee for Determining and Approving Terminology in Geology (1993). In many local mine areas, sedimentary formation names and the names for structural features may differ, because of old and new names, and because of the use of different names by different Provincial Geologic Bureaus. Assignment of nomenclature and age assignment of units to local mine areas may also vary, because a number of relatively independent geologic governmental agencies have conducted work in some areas. These differences in nomenclature use take place at local and provincial levels in daily usage, on mine maps and in written reports and published literature.

REGIONAL GEOLOGIC SETTING

The Dian-Qian-Gui area lies along the southwest margin of the Yangtze Precambrian craton, in the northern Nanpanjiang orogenic fold zone, at the join between the Tethyan-Hemalayan and Pacific Ocean tectonic plates (Zheng, Z.H., and others, 1984; Ji, X., and Coney, 1985; Wang, Y., 1992; Yin, A., and Nie, 1996). Regionally, tectonic units in the Dian-Qian-Gui area belong to the northwest-trending Wangmei deformation zone, which is a triangular-shaped area surrounded by north-northeast- northwest-, and east-west-striking structural zones (Dong, S.B., 1993). Along the Leping–Xingyi–Zhengfeng–Anshun tectonic boundary (not shown on figures), sedimentation was controlled by a paleo-tectonic basin that changed from Upper Paleozoic to Lower Mesozoic, such that the northwestern parts of the basin contain Paleozoic sedimentary rocks developed along a broad, restricted platform environment, which then evolved into a tidal flat in the Lower Triassic (Deng, S.S., and others, 1986; Yang, Z., and others, 1986; Hsu, K.J., and others, 1996)

Sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area were formed in a tectonic and sedimentary environment along the juncture between the Yangtze craton and Youjiang orogenic belt (figs. 3-1, 3-2, 3-3, and 3-4). From Upper Paleozoic to Lower Mesozoic, this area consisted of shallow- and deep-water sedimentary environments along the northeast-trending southwest margin of the Yangtze craton (fig. 3-3). Platform, shallow-water (miogeosynclinal) assemblage, carbonate-bearing sedimentary rocks were deposited on the northwest part of continental shelf of the carton during the Upper Paleozoic and Lower Mesozoic. Limestone and bioclastic limestone were deposited during the Carboniferous and are overlain by Permian cherty limestone, bedded limestone, bioclastic limestone, and tuffaceous

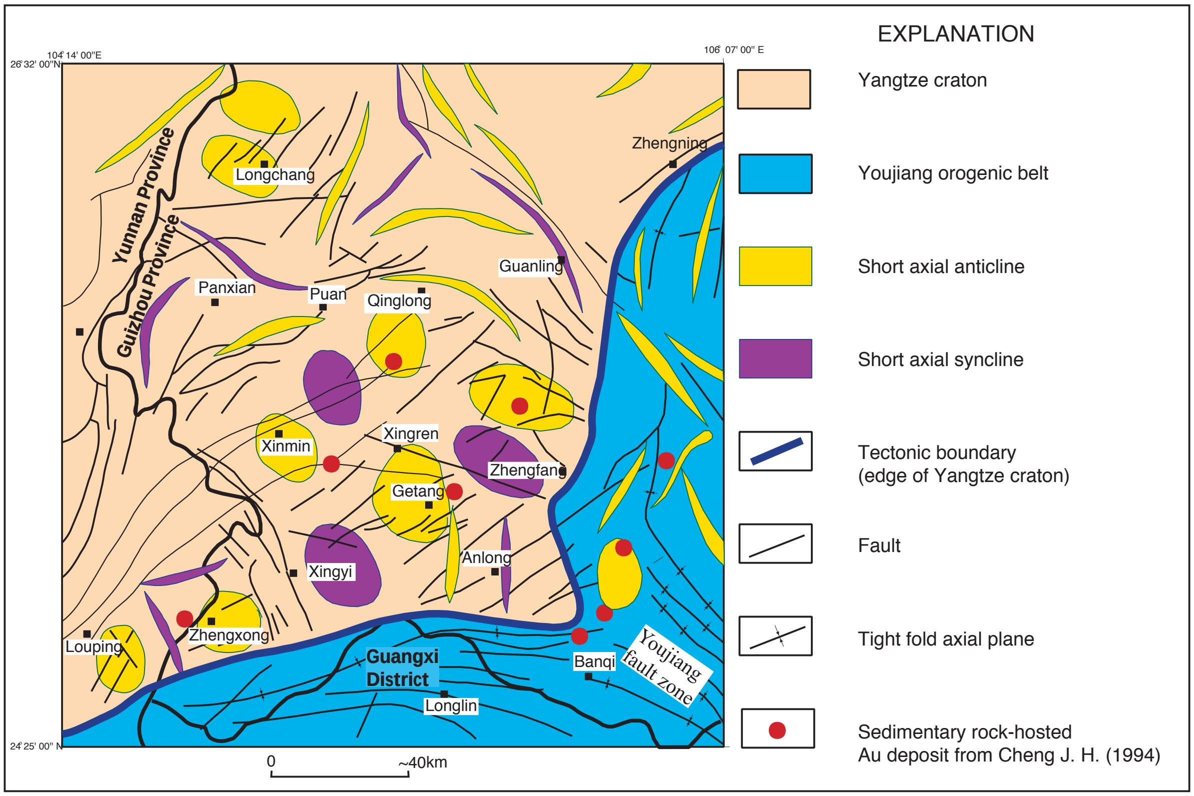

Figure 3-2. Regional structural framework of the Dian-Qian-Gui area near the Guangxi District-Guizhou Province boundary adapted from Cheng, J.H. (1994) and Li, Z.P. and Peters (1998), showing the difference in structural patterns between the platform area of the Yangtze craton, which contains short-axial anticlines (domes) and synclines (basins) in northwest Dian-Qian-Gui, and the adjacent basin area of the Youjiang orogenic belt in the southeast, which contains tight folds and thrust faults. County cities are shown by dark squares.

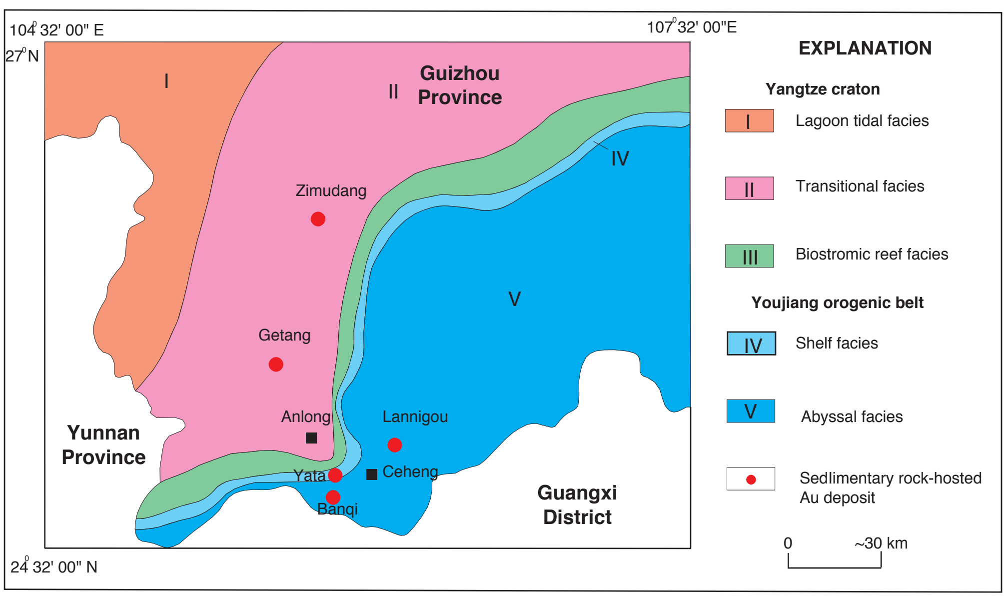

Figure 3-3. Sedimentary facies of Middle Triassic rocks in the Dian-Qian-Gui area in Guizhou Province showing the distribution on Yangtze craton and in the Youjiang orogenic belt. Some sedimentary rock-hosted Au deposits identified in Li, Z. P. and Peters (1998) are shown as red circles. County cities are shown as open squares. Compiled and adapted from Yao, Z.Y (1990).

argillite. These calcareous rocks commonly form karst terrane in the interiors of domal structures (fig. 3-5). These carbonate rocks are, in turn, overlain by Triassic argillite, limestone, and dolomite. Coeval deep basin (euogeosynclinal) assemblage rocks consist of siliciclastic rocks, including feldspathic greywacke, siltstone, and argillite, which formed in the southeast part of the basin. Sedimentary rock-hosted Au deposits are present in both deep- and shallow-water facies rocks, but are associated with distinct geological and geochemical features in these two parts of the basin.

Airborne magnetic data show that the upper crust in the Dian-Qian-Gui area is made up of discrete tectonic blocks that have been interpreted by Wang and others (1994) to have been subjected to different types of stress. The expression of this tectonic pattern is clearest in southwest Guizhou Province (fig. 3-4; see also, Appendix I), where the Yangtze craton mainly consists of weakly strained, separate blocks, while the Youjiang orogenic belt to the southeast is composed of a single, strongly strained block (fig. 3-4). The contact between these two tectonic units is a series of large-scale thrust structures (Wang, Y., 1992; Wang, Y.G. and others, 1994). The structural pattern also is different in these two tectonic units along the margin of the Yangtze craton (figs. 3-3, 3-4). On the northwest side, in the carbonate platform rocks, brittle faults and structural domes are more common, whereas tight folds and low-angle ductile-brittle thrust faults are more common in deep basin rocks to the southwest in the Youjiang orogenic belt (Luo, X.H., 1994).

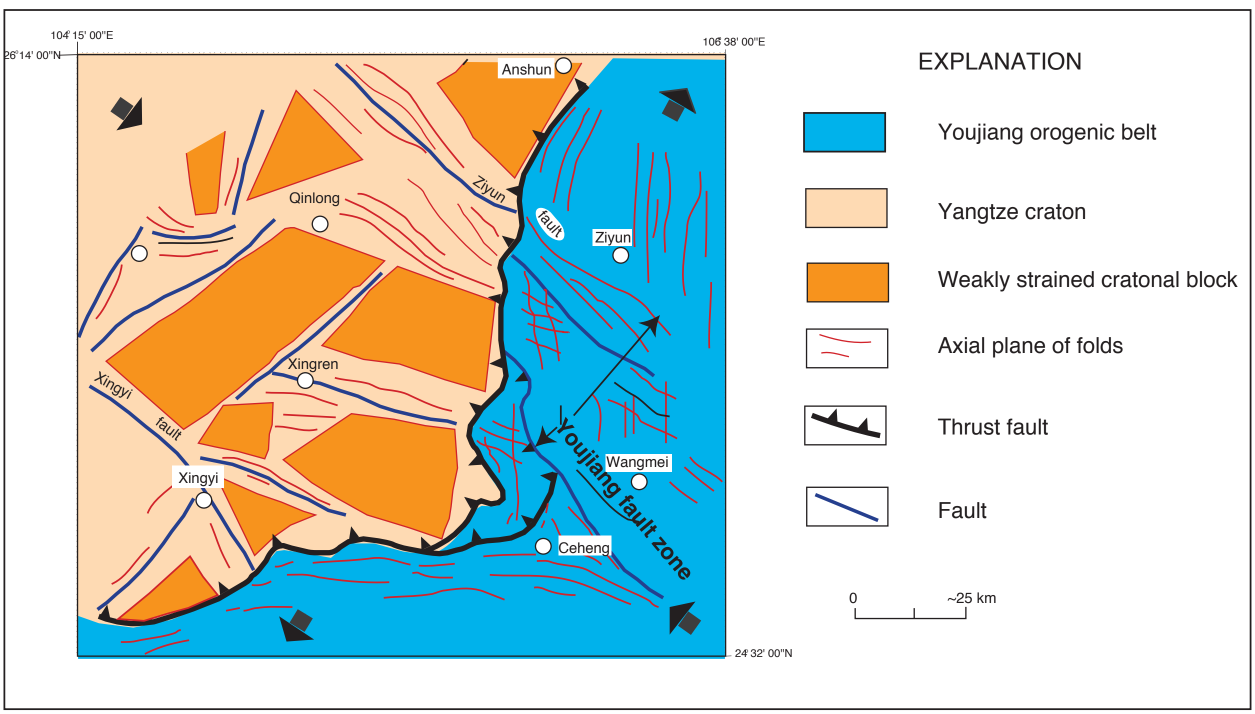

Figure 3-4. Interpretive map of the structure of the upper crust in the southwest part of Guizhou Province, Dian-Qian-Gui area, interpreted from areomagnetic data. Arrows show the directions of Mesozoic and Tertiary compression and extension; County cities are shown open circles. Note location of the Youjiang fault zone. Bold arrows show probable stress field directions. Area covered by map is roughly the same as that covered by figs. 3-1, 3-2, and 3-6. Adapted from Wang, Y.G. and others (1994) and reproduced from Li, Z.P. and Peters (1998).

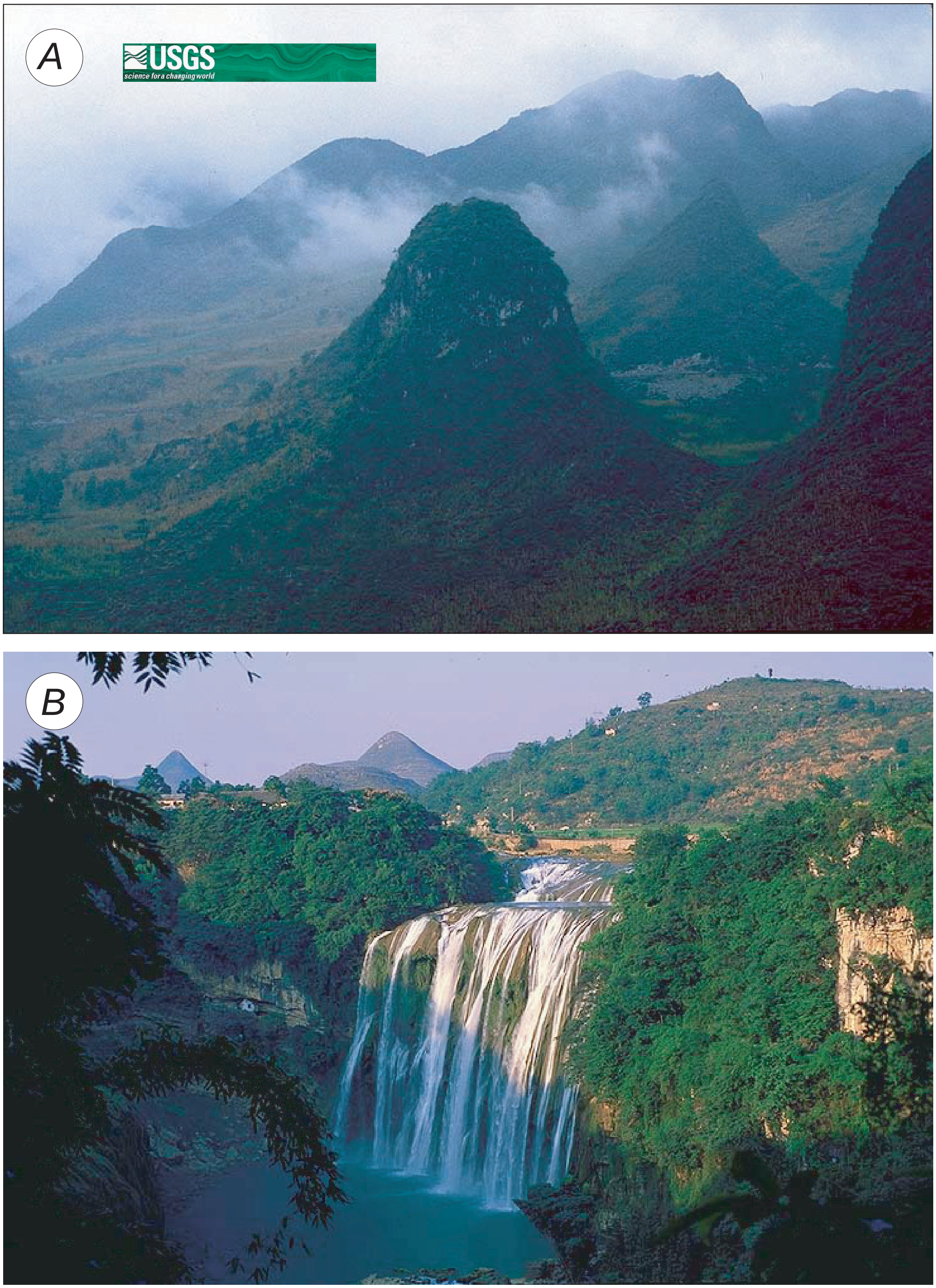

Figure 3-5. Examples of karst topography in Dian-Qian-Gui area, Guizhou Province.
(*A*) Rounded limestone hills and karst low lands. (*B*) Huangoushu Water Falls spilling into sink hole.

The northwest-trending Indosinian-Yanshanian age (230 to 67 Ma) Youjiang fault zone or fault system is part of the Youjiang orogenic zone (including a number of northwest-striking faults, such as the Xingyi and Ziyun faults) that crosses the boundary between the Yangtze craton and the Youjiang orogenic zone and has been interpreted as an extensional structure that post-dated compression tectonism in the region (fig. 3-4). Distribution of sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area is spatially related to the Youjiang rift fault system (Tan, Y.J., 1994). The Youjiang fault zone is likely a deep basement structure. A 100-km wide buffer around the fault trace encompasses most of the sedimentary rock-hosted Au deposits (fig. 3-6) (see also, Chapter 6). Similar regional-scale abrupt tectonic lineaments are present in northern Nevada and may control or align some clusters of Carlin-type deposits (Grauch and Bankey, 1991; Grauch and others, 1995; Grauch, 1996; Peters, 1998, 2000a) (fig. 3-1).

Host rocks in the Dian-Qian-Gui area mainly are Paleozoic and early Mesozoic siltstone, argillite, and impure limestone, although some units contain tuffaceous horizons. Gabbroic diabase hosts some ores in eastern Yunnan Province at the Jinba Au deposit. A very important feature in most of the deposits, similar to Nevada Carlin-type Au deposits (Arehart, 1996), is the presence of impure carbonate and calcareous clastic rocks that represent a transitional zone of sedimentary facies. These transitional clastic rocks are very favorable host rocks, because dissolution from the ore fluid preferentially removed carbonate grains and cement and left a porous, siliceous or dolomitic rock that could be more easily penetrated by the ore fluids. For example, in the Zimudang Au deposit, the main host rocks are argillite, silty argillite, basaltic tuffaceous siltstone, and silty dolomite. Rocks near the Zimudang orebody are brecciated by faults and are strongly silicified. Gold orebodies are present along these faults and the largest tonnages and grades are located where argillite and clastic rocks intersect the fault. There is little ore or no Au-mineralized rock in thick dolomite and limestone, which also intersect the faults (Peng, Y.Q., 1994). Igneous rocks are sparse or lacking in the Dian-Qian-Gui area.

Domes or short-axial anticlines—defined as folds with a length in the axial direction roughly equal to its limb widths—are common and important ore-controlling structures in the Dian-Qian-Gui area (figs. 3-1, 3-2 and 3-6). Almost all sedimentary rock-hosted Au deposits are spatially related to folds or domes in the region (Luo, X.H., 1994; Wang, Y.M., and others, 1996). For instance, the Gaolong Au deposit is controlled by the Gaolong short-axial anticline that is associated with a set of arc faults. The Gedang Au deposit is controlled by bedding-parallel faults in the two limbs of the Jiusai dome. In addition, the Banqi Au deposit is controlled by the Naban fold (fig. 3-26); the Lannigou Au deposit is on the margin of the Laizishan dome (fig. 3-13). In a similar way, the Zimudang Au deposit is controlled by the west part of the Huijiapu anticline, and the Sanchahe, Puzilong, and Beiyinpo Au deposits (prospects) (Li, Z.P., and Peters, 1998) are located on the eastern side of the Huijiapu anticline. Similarly, the Getang Au deposit is present in the Daba dome. Sedimentary rock-hosted Au deposits typically cluster along fault and shear structures on the outer most parts of the domes near the contact between upper Paleozoic carbonate and Triassic siliciclastic rocks.

Structural domes in southeast China are generated by the interference of two fold systems crossing each other, similar to refolding or partial doming. High-angle breccia zones and detachment faults commonly host Au orebodies on the margins of these domes at the interface between the underlying carbonate rocks and the overlying siliciclastic rocks. The Laizishan dome that hosts the large Lannigou Au deposit is a typical example and is 25 km long and 12 km wide (figs. 3-1, 3-33). The central domal area of the Laizishan dome is comprised of approximately 1,300 m of Carboniferous to Permian limestone, bioclastic limestone, and reef limestone, with interlayered argillite and tuffaceous argillite (Dachang unit). Triassic turbidite sequences (1,000 m thick) are distributed on the west and east limbs of this dome. Faults surrounding this short-axial anticline are well-developed, and are spatially associated with Au, As, Hg, and Sb mineral occurrences and deposits, such as the Bannian, Yangyou, Pogao, and Luodong Au deposits, and the Qingping, Tangxinzhai Au prospects (not all shown on figs. 3-1, 3-13) (Luo, X.H., 1994; Li, Z.P., and Peters, 1998).

Because sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area usually are stratabound and show strong stratigraphic control, three sedimentary or volcanic horizons are considered by Tan, Y. J. (1994) to be possible source-beds for the Au in the deposits: (1) Early Devonian and late Permian terrigenous clastic volcanoclastic rocks host Au–Sb–pyrite deposits and occurrences in the northwest part of the Dian-Qian-Gui area, including the Gedang, Maxiong, Getang, and Dachang Au deposits; (2) Permian carbonate-bearing clastic rocks host Au–Hg–Tl occurrences and deposits in the northwest part of the Dian-Qian-Gui area, including the Zimudang Au deposit; and (3) Triassic turbidite deposits are associated with Au–As–(Sb) mineralized occurrences in the southeast part of the Dian-Qian-Gui area (Tan, Y.J., 1994; Huang Y., 1993) (see also, Chapter 1).

A related theory of metallogenesis to the source bed theory of Tan, Y.J. (1994) is the suggestion that sedimentary rock-hosted Au deposits may directly be related to carbonaceous material in the sedimentary pile (Zheng, Y.F., and Yin, H.S., 1994). The genetic association is speculated to be related to the formation and mobilization of petroleum and Hg (Lu, G.Q., and others, 1992; Liu, J.Z. and others, 1992; Huang, G.S., and Du, Y.Y., 1993). The process may also be related to As-, Au-, and Tl-bearing coal horizons (Huang, Y., 1993). The association of Carlin-type sedimentary rock-hosted Au deposits with carbonaceous sedimentary rocks and remobilized carbon in these deposits also is a common one in Nevada (Ballantyne, 1988; Kuehn and Rose, 1992; Peters and others, 1998, 2000a,b).

Tectonic influences, structural control, and genesis of sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area have been suggested by Wang, Y.G. and others (1994) and Luo, X. H. (1993, 1996), particularly with respect to the Lannigou, Yata, and Banqi Au deposits. These deposits, and some in Nevada (Peters and others, 1998, 2000a,b), and the Qinling fold belt (see also Chapter 4), contain rocks and ore textures, which indicate that dissolution by hydrothermal fluid was part of a direct interaction between the fluid and deformation, suggesting a syndeformational genesis. On a regional-scale, hydrothermal fluids may migrate along deep-seated fluid conduits, as suggested in Nevada by Peters (1998, 2000a, b) or in the Dian-Qian-Gui area along the Youjiang fault zone as illustrated in figure 3-6.

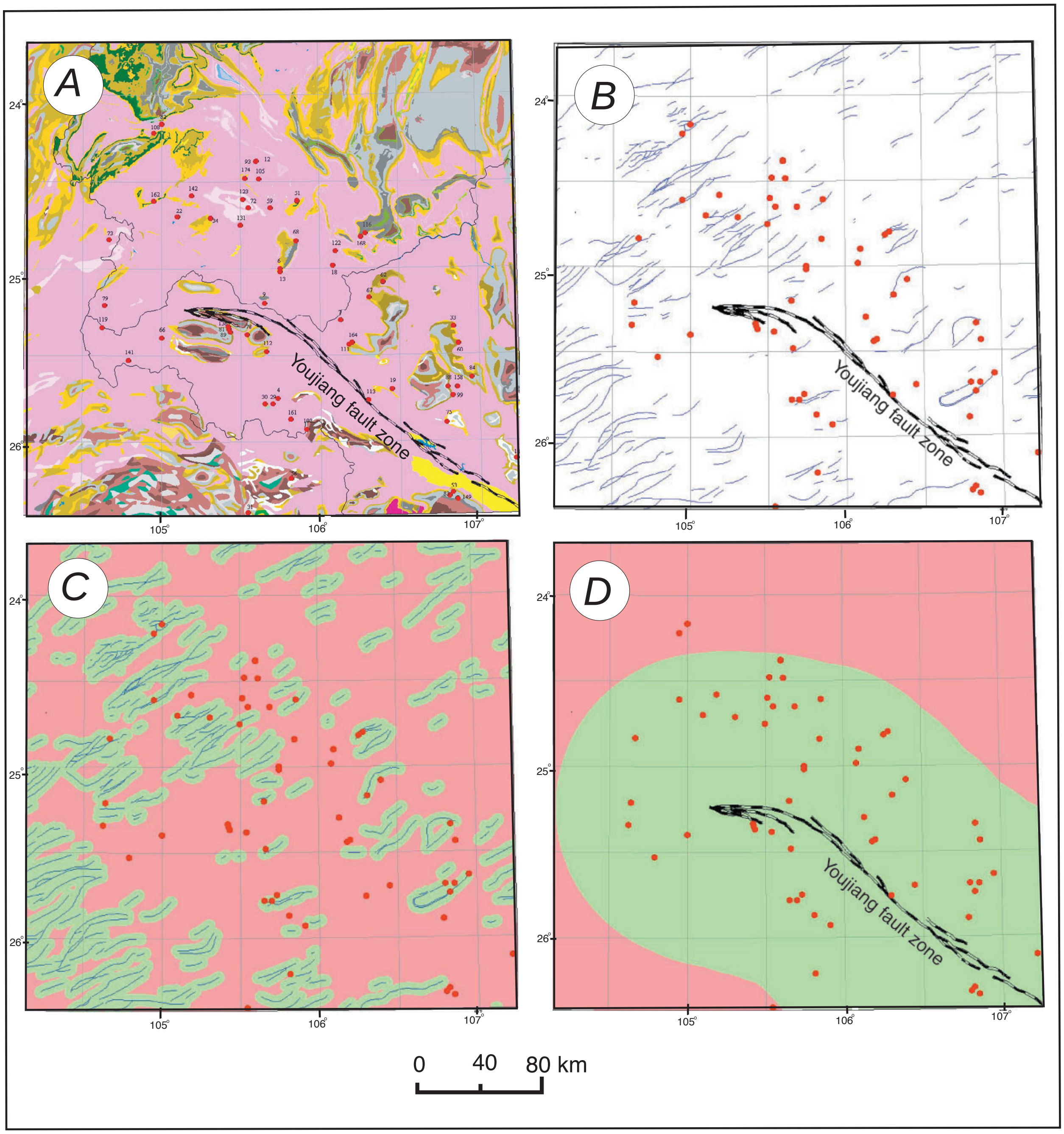

Figure 3-6. Regional geologic and structural control of sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area, P.R. China. (*A*) Geologic map showing distribution of deposits in Triassic sedimentary basin (purple) and near domes (bright-colored areas (Fig. 3-1). (*B*) Northeast-striking faults (light lines). Note that these faults are not common near Youjiang fault zone. (*C*) Buffered areas around northeast-striking faults (light green) corresponds with many Au deposits. (*D*) 100-km-wide buffer around the Youjiang fault zone (green) that encompasses most of the sedimentary rock-hosted Au deposits. The shape of the cluster of deposits closely follows the shape of the buffer around the Youjiang fault zone suggesting that the deposits may be related to the fault zone. One possible theory is that fluid emanated from the fault zone along the northeast-striking faults and then was guided to individual ore deposits near the structural domes by district-scale faults.

DESCRIPTIONS of Au DEPOSITS

The following ore deposit descriptions are summarized from field observations, compilations, and resulting laboratory investigations from visits in 1997 to the Zimudang and Lannigou Au deposits in Guizhou Province, and the Gaolong and Hengxian Au deposits in Guangxi District, and from visits in 2000 to the Gedang and Jinba Au deposits in Yunnan Province. In addition, literature compilations are included for descriptions of the Banqi, Yata, Getang, Sixianchang (Au–Hg), and Jinya deposits in the Dian-Qian-Gui area (see also, Li, Z.P. and Peters, 1998; and Appendix IV).

Zimudang Au deposit

The Zimudang Au deposit is situated in Xingren County, Guizhou Province about 31 km northeast (in a 60∫ direction), from the Xingren County town at 105° 027’ 36" E, 25° 034’ 22"N. The deposit lies along the south-dipping F_2 fault in a breccia zone (fig. 3-7). The No.1 orebody is 850 to 1,000 m long, 0.7 to 24.29 m thick, and extends 400 to 500 m deep. The grade is 5.95 g/t Au. The No. 2 orebody is 850 m long and 400 to 500 m deep. The reserve of the Zimudang Au deposit is more than 32 tonnes Au. Information for the deposit is from field and laboratory work gathered during a 1997 visit and from Chief Chen and Xin Xunfeng, Guizhou Bureau of Geology and Mineral Resources (see also, Guo, Z.C., 1994; Peng, Y.Q., 1994).

Mining (1997) is confined to the oxide zone and is done both by back-hoe and by hand methods along a 1–km-long, northwest-trending open pit centered on the host breccia zone of the F_2 fault (figs. 3-8 and 3-9). Ore is trammed by hand from back-hoe stockpiles or from handed-worked areas in shoulder-carried double baskets (fig. 3-10) to a hopper and grizzly and then crushed (figs. 3-8, 3-9) and trammed by hand to heap-leach piles and treated with cyanide. Hypogene ore is sorted and stockpiled.

Sedimentary strata exposed in the Zimudang Au deposit area are the Lower Permian Maokou Formation (P_1m), Upper Permian Longtan (P_2l), Changxin (P_2c) and Dalong (P_2d) Formations, and Lower Triassic Yelang (T_1y) and Yuning (T_1yn) Formations (fig. 3-7). Gold orebodies mainly are hosted in fine-grained clastic and impure carbonate rocks of the P_2c, P_2d, and T_1y, units that are composed of:

(P_2c) bioclastic limestone intercalated with claystone. Organic material is common in the rock. Thickness is 50 to 57 m.

(P_2d) calcareous claystone. Thickness is 7 to 13.5 m. In the top, there is thin-bedded limestone.

(T_1y) is divided into three members:

- (T^1y^1) siltstone, silty claystone, claystone, muddy limestone, dolomitic limestone, and bioclastic limestone, 176 to 227 m thick.
- (T_1y^2) oolite-bearing limestone, bioclastic limestone, dolomitic limestone, muddy limestone that is intercalated with arenaceous claystone and argillic siltstone, 115 to 136 m thick.
- (T_1y^3) silt claystone, argillic siltstone, intercalated with oolite-bearing limestone, and muddy limestone, 140 m thick.

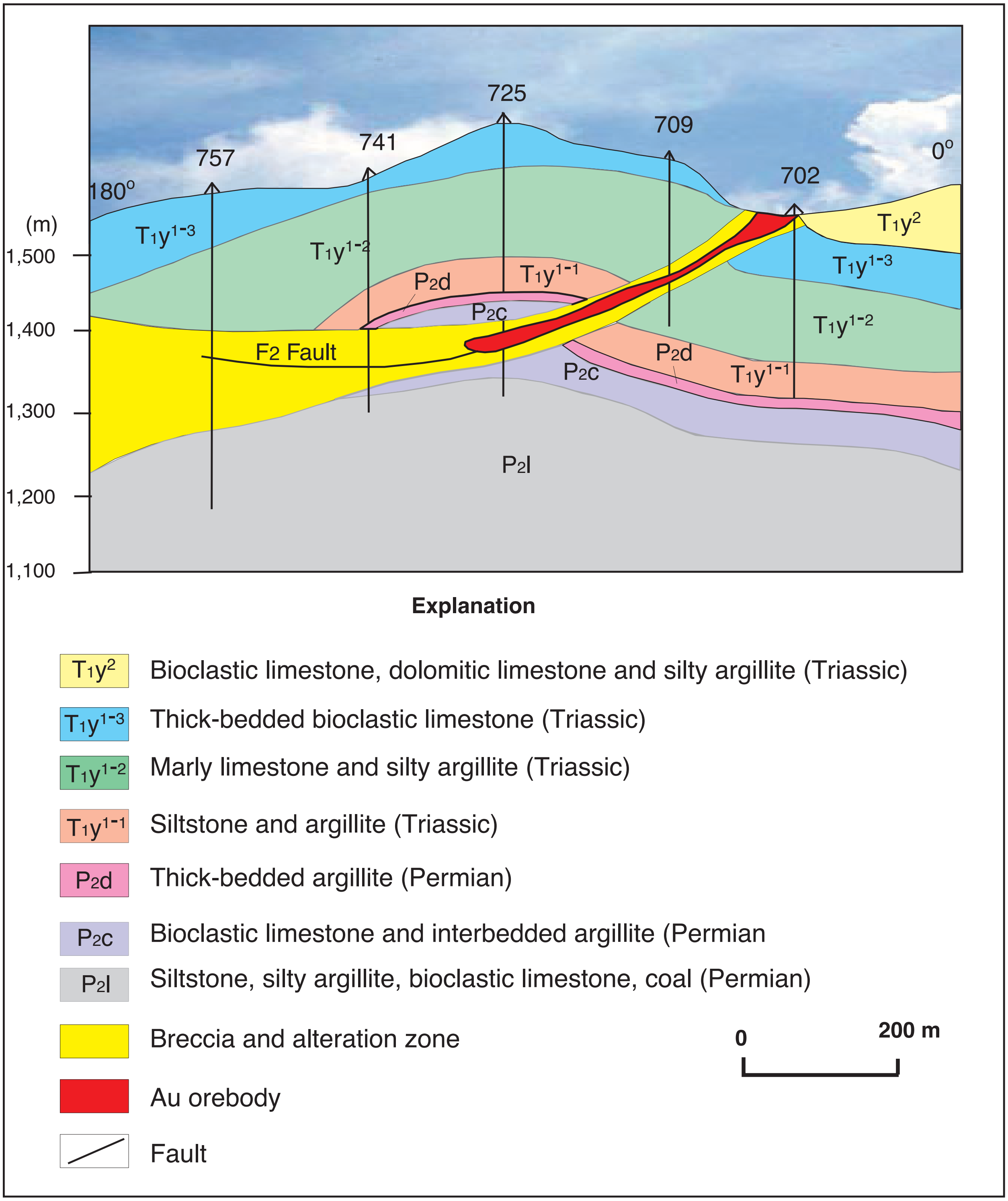

Figure 3-7. Geologic section of the Zimudang Au deposit, Guizhou Province, Dian-Qian-Gui area. Joints associated with fault and anticlines provide the localizing host structure for the ore. Drilling holes (757, 741 etc.) schematically represented. Looking west. Adapted from Gou, Z.C. (1994).

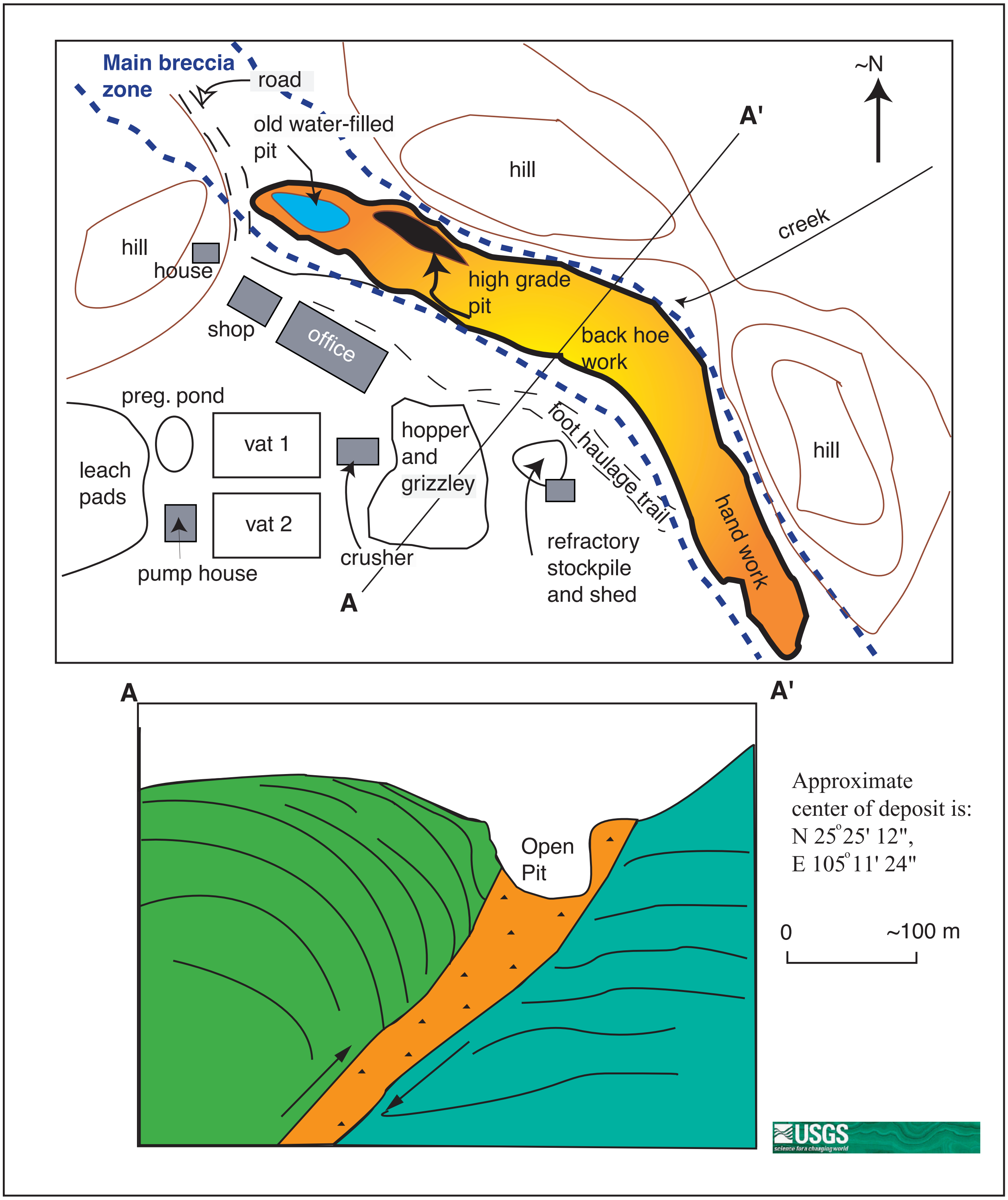

Figure 3-8. Sketch map and schematic cross section of the Zimudang Au deposit area, Guizhou Province, Dian-Qian-Gui area, showing layout of the mine area and plant. Cross section shows sketch of breccia zone that hosts the main ore zone.

Structurally, the Zimudang Au deposit is located along the north margin of Youjiang fold belt of the South China fold system. The Au deposit is on the west end of the district-scale, northwest-trending Huijiapu dome (fig. 3-1). Gold is closely controlled by the east-west-trending F_2 thrust fault that dips south 25 to 30° along the north limb of the dome (figs. 3-7 and 3-8). Host F_2 fault zone in the oxide zone is yellow to brown consisting of limonite-clay matrix-supported breccia with centimeter-scale hetrolithic clasts that are intensely altered to white and yellow clay (fig. 3-11). The breccia zone and adjacent wall rocks are altered and form a 25– to 50–m-thick, planar envelope that encases the orebodies. Host breccia displays textures indicating multiple brittle brecciation events. Favorable stratigraphic units adjacent to the F_2 fault also contain disseminated Au-bearing sulfide grains.

Ore minerals in hypogene ores of the Zimudang Au deposit mainly are pyrite, marcasite, arsenopyrite, realgar, and native Au, with rare chalcopyrite, sphalerite, galena, and Ti-, Zn-, Fe-sulfide minerals (figs. 3-11 and 3-12). Gangue minerals are calcite, dolomite, quartz, and hydromica with girdle, replacement, cataclastic, inclusion, and interstitial textures. The sulfide and gangue minerals are present as disseminated, network, brecciated, and pseudo-brecciated

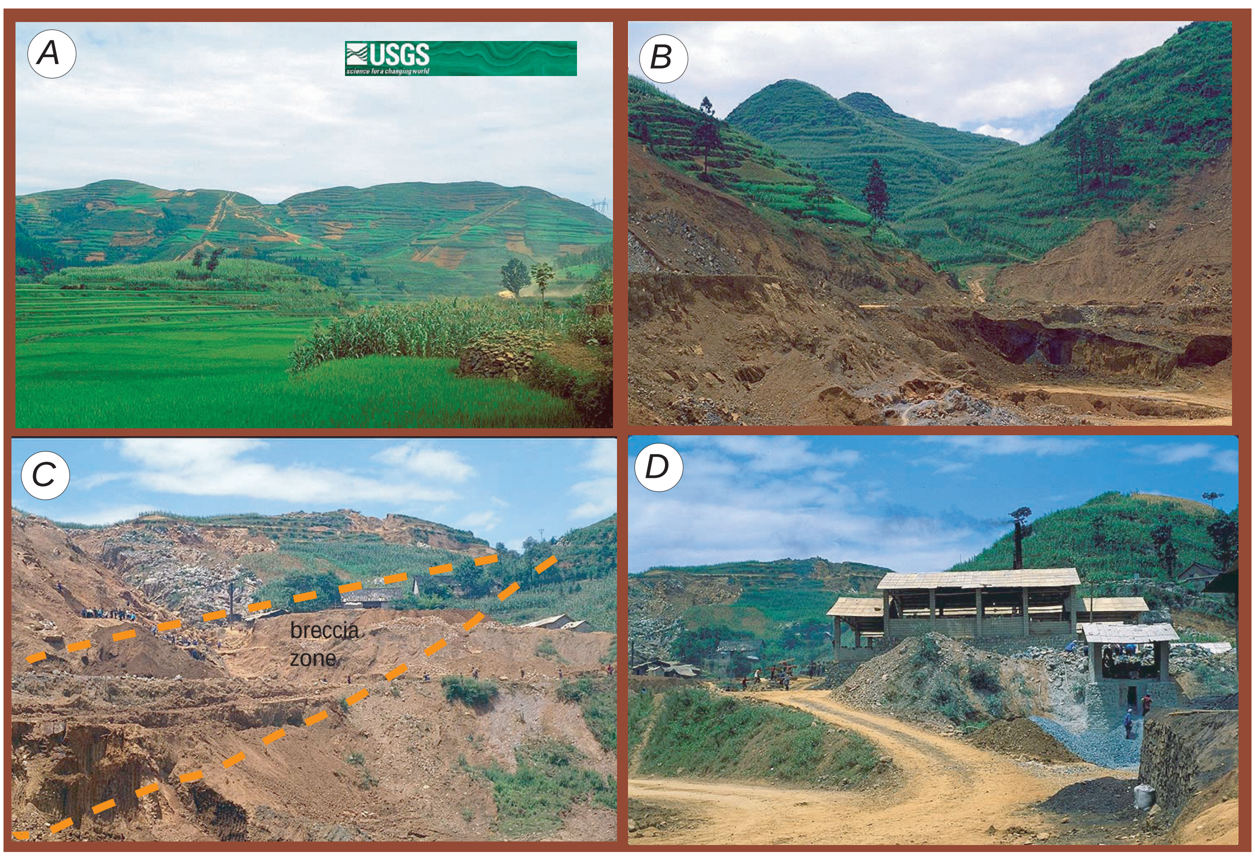

Figure 3-9. Photographs of Zimudang Au deposit and Mine area, Guizhou Province, Dian-Qian-Gui area. (*A*) View from east foot wall of the deposit looking from the northwest. Deposit is on other side of hill and exploration scars are apparent on hillside. (*B*) View of main lode on east side of mine, looking east. (*C*) View of east side of mine, showing lode, looking west. (*D*) Main loading hopper for oxide ore. Heap leach piles are located to the right of hopper.

textures. Gold minerals mainly are present as inclusions of Au (80 weight percent), as well as free Au (20 weight percent). Grains of Au are very fine (<1 μm). Pyrite, arsenopyrite, calcite, dolomite, and clay minerals are the main carriers of Au. Hydrothermal alteration is closely related to Au and mainly consists of silicification that is accompanied by the addition of pyrite and realgar. Limonite is prevalent in the oxide zone (fig. 3-11).

Geochemically, the ores of the Zimudang Au deposit contain elevated or anomalous concentrations of As, Sb, Zn, Ni and moderately high concentrations of Cu and Tl (Appendix IV). The ores are characteristically low in Bi and other geochemical indications of pluton-related processes. The elevated geochemical suite is characteristic of Carlin-type deposits (see also, Percival and others, 1988; Dean and others, 1988) and also is similar to the regional-scale anomalous background geochemical concentrations of some of the host stratigraphic units (Tan, Y.J., 1994).

Figure 3-10. Photographs of mining methods at the Zimudang Au Mine, 1997, Guizhou Province, Dian-Qian-Gui area. (*A*) Hand-tramming of ore in double baskets. (*B*) Mining of eastern lode by hand and hand-tramming. (*C*) Empty baskets on back haul toward mining face on east side of deposit in oxide zone (between dashed lines). (*D*) Hand mucking from back-hoe trench in central part of lode and stock-piling for truck haulage.

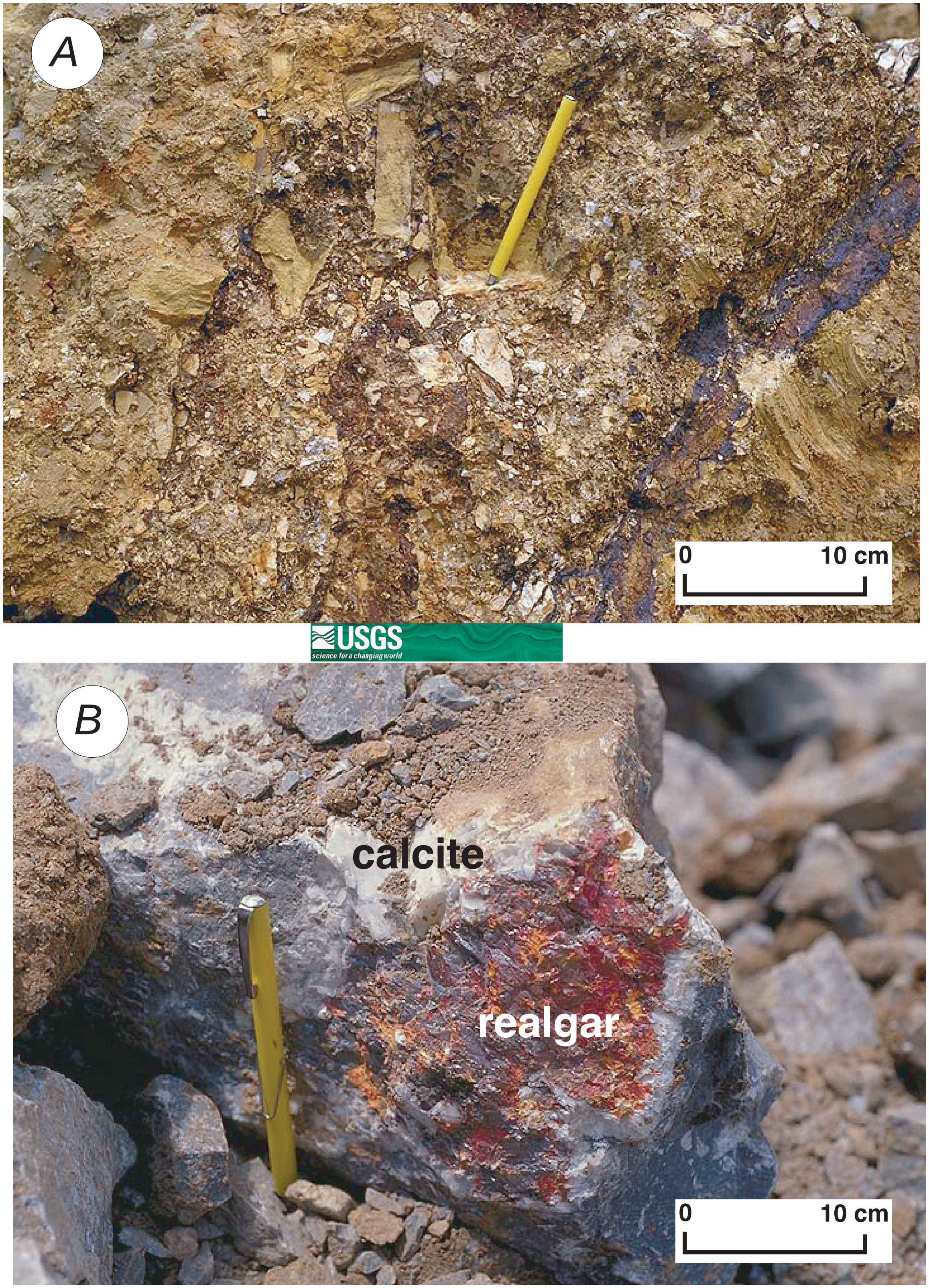

Figure 3-11. Photographs of ores from Zimudang Au deposit, Guizhou Province, Dian-Qian-Gui area. (*A*) Breccia zone with sub-angular clay altered clasts in flower and fragmented matrix in main breccia zone. (*B*) Calcite and realgar in calcareous fine-grained sandstone. (Adapted from Li, Z.P. and Peters (1998).

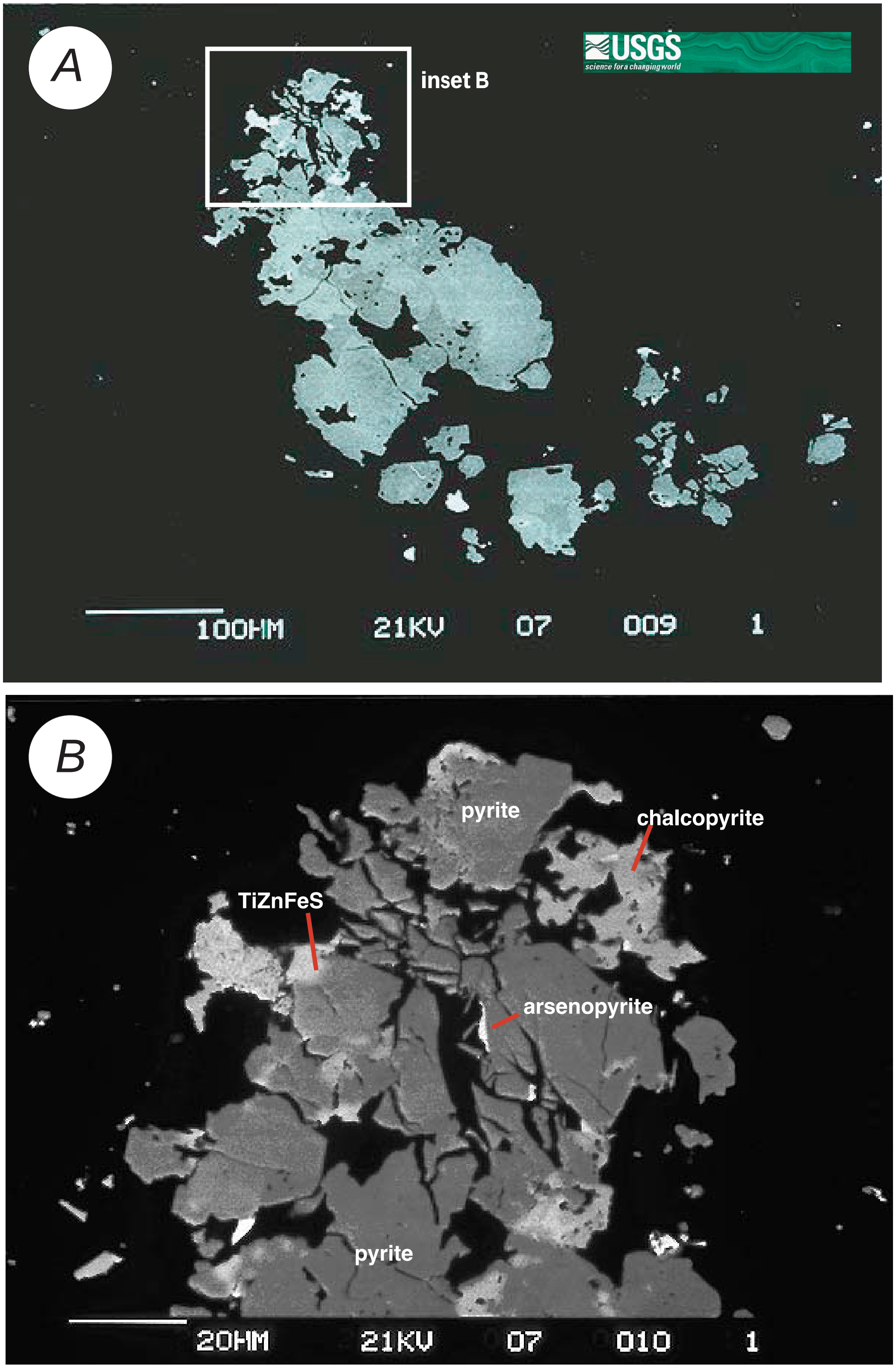

Figure 3-12. SEM back scatter images of polymetallic sulfide minerals from Zimudang Au deposit, Guizhou Province, Dian-Qian-Gui area. (*A*) Composite pyrite grain from disseminated cluster of sulfide minerals. (*B*) Chalcopyrite, arsenopyrite and Ti-Zn-Fe-S trace minerals in pyrite in inset part of larger grain in A.

Lannigou Au Deposit

The Lannigou Au deposit is located on the banks of the Beipanjang River in southeast Zhengfeng County, Guizhou Province on the flanks of the Laizishan dome (figs. 3-1 and 3-13) and is the largest Au deposit in the Dian-Qian-Gui area and the largest sedimentary rock-hosted Au deposit in China (Li, Z.P. and Peters, 1998) (see Appendix III for coordinates). The deposit was an As (orpiment) prospect that was discovered by the Regional Geological Survey Team, Bureau of Geology of Guizhou Province, in 1986, and has been evaluated by the 117th Geological Team of the Bureau. This deposit has been listed as one of the "892 National Plan" projects because its orebodies are thick and rich and have significant economic potential. The climate is semi-topical and intense weathering has produced a 20–m-thick clay-rich profile (fig. 3-14). Lannigou means "valley of sticky mud". Information for the Lannigou Au deposit is from Lou, X.H., (1994) (translated in Li, Z.P. and Peters (1998) and from a 1997 field visit and from Chief Chen and Xin Xunfeng, Guizhou Bureau of Geology and Mineral Resources.

The Lannigou Au deposit has four main segments, No 16, Nos. 2 and 3, and No. 1 orebodies, plus a significant number of peripheral prospects around the Liazishan dome (figs. 3-13, 3-15). The No. 1 orebody, located in the Huangchanggou block, has been proven to be large in size, while the deposit as a whole is extra-large in size (>100 tonne Au). This Au deposit is considered to be mineable because of its uniform thickness, even grade, good hydrogeology, metallurgy, and suitability for open pit mining. The upper oxidized parts of the orebodies have been amenable to cyanide processing.

The S-shaped, 155–m-long No. 1 orebody along the F_3 fault is situated high on a central upland surrounded by a low valley and is exposed for 500 m along strike on the surface, and joins the No. 2 orebody on its west end (fig. 3-16). The measured maximum strike length of the orebody is 680 m, and 570 m down dip, and it is still open at depth and to the east. The No. 1 orebody has an average thickness of 10.70 m, and varies from 5.77 m to 19.77 m, and up to 33.01 m thick. Gold assay values average 7.01g/t Au and vary from 4.01 to 11.01 g/t Au, and up to 13.82 g/t Au. There are three Au-rich blocks in the No. 1 orebody.

The Lannigou Au deposit, is located on the eastern limb of the Laizishan short-axial anticline or dome (figs. 3-1, 3-13) (Luo, X.H., 1994; Li, Z.P. and Peters, 1998), which is part of the Yidu-Ziyun northwest-trending structural zone (not shown on figures). Gold orebodies are controlled by these structures (fig. 3-15). The Lannigou, Bannian, Yangyou, Banqi, and Yata deposits, in addition to the Pogao and Luodong Au prospects, and the Qingping and Tangxinzhai Au anomalies and other As, Sb, Hg mineralized areas present in this area, all surround the Laizishan dome (prospects not all labeled on figure 3-13; see Appendix III). The principal type of mineralization found is sedimentary rock-hosted disseminated Au along with associated metals.

Sedimentary rocks hosting Au are divided into two early to middle Triassic facies; the first is a continental slope facies formed between the margin of a platform and a deep rift basin (fig. 3-3); the second is a group of clastic rocks of terrigenous origin (fig. 3-13). According to Luo, X.H. (1994, 1996), these rocks not only host Au ore, but also are the source beds for the ore-forming materials.

Stratigraphic units in the Lannigou Au deposit area in the center of the Laizishan dome are the Middle to Upper Carboniferous Huanglong Formation and Upper Carboniferous Maping Formation, consisting of light gray, massive limestone and bioclastic limestone. The Lower Permian Qixia and Maokou Formations that are composed of cherty limestone, bedded limestone, bioclastic limestone, and argillite and tuffaceous argillite in "the Dachang Layer" overlie these rocks. These rocks are overlain by late Permian rocks of the Wujiaping Formation that consist of limestone and reef limestone and are overlain by the Triassic Yelang and Anshun Formations consisting of argillite, limestone, and dolomite (fig. 3-13).

By contrast, Triassic sedimentary rocks that surround the Laizishan structural dome formed in a terrigenous basin as a sequence of thick-bedded clastic rocks. The Lannigou Au ore deposit is hosted in two distinct sets of these Triassic sedimentary rocks. Upper Triassic rocks are exposed in the western limb of the Laizishan dome and are shallow-sea carbonate rocks formed in a continental shelf environment along the margin of the Yangtze craton. Early to Middle Triassic rocks are exposed along the eastern limb of the anticline and host the main Au ore deposit. They are up to 1,000–m-thick, terrigenous calcareous flysch and turbidite deposits formed in an abyssal environment of the Youjiang rift basin. Stratigraphic units involved include the Lower Triassic Luolou, Formations, and the Middle Triassic Yinyaun (Xuman) and Bianyang Formation (fig. 3-13).

The 270–m-thick Middle Triassic Bianyang Formation (T_2b) is conformable with the underlying strata and consists of thin- to medium-thick layered, fine-grained sandstone, and siltstone with interbedded argillite or alternating beds of sandstone and argillite. All of the main Lannigou Au deposits are present in these rocks, particularly in the bottom parts of the unit. The Lower Triassic Xinyuan Formation (T_2x) decreases in thickness to the west (in the Huangchanggou area), while increasing thickness to the east (Lannigou and Lintan areas) and also is unconformable with the underlying strata. The Xinyuan Formation is divided into four members composed of argillite, limestone, and sandstone. Sandstone in the third member contains coarse cubic pyrite, and scattered pelletal pyrite. Strong Au concentrations are associated where the F_3 fault cuts through this stratigraphic unit.

Lower Triassic rocks also include: (1) Luolou Formation (T_1l, 0 to 76.25 m thick) that is distributed in the north part of the Lannigou Au deposit, and consists of gray to dark gray limestone, interbedded with argillite and tuffaceous argillite; (2) Lixue limestone (Lx) located in the southern part of the Lannigou ore district, and is composed chiefly of calcirudite, limestone breccia, micritic limestone, and bioclastic limestone. Upper Permian rocks are represented by the Wujiaping Formation (P_2w) and are comprised of bioclastic limestone and reef limestone.

Igneous rocks are limited in the Lannigou Au deposit area, except for a few small alkalic, ultramafic intrusions (porphyry cascadite, fasinite, and cuselite) exposed in the area between the towns of Zhengfang and Baiceng about 27 km northeast of the Lannigou Au deposit (not shown on figures) (Luo, X.H., 1994).

The structural history of the Lannigou Au deposit area from the Indosinian-Yanshanian (230 to 67 Ma) orogeny that is divided into four general stages. Cross cutting relations suggest that the regional stress field varied during these four stages from north-south, to east-west, then to northeast-southwest, and finally to northwest-southeast (Zheng, M.H., 1989). The changing stress field formed a structural pattern in the Lannigou Au deposit area that resulted in the Laizishan dome (short-axial anticline) and the Banchang thrust fault (not shown on figures) and a number of steep-dipping faults that are the most important structural features in the evolution of the deposit (fig. 3-15).The Carboniferous to Triassic rock sequence displays brittle deformation, such as faults and joints that often form grid-shaped structural patterns, that are developed by the intersection of steep-dipping, north-south-, northeast-, and northwest-striking faults. Terrigenous rocks in the southeast part of the Lannigou area are characterized more by ductile deformation features, such as tight folds and thrust faults. Most thrust faults strike northwest and north-south.

Northeast-striking faults also are present in these rocks as shear zones that cut the thrust faults. Fold axial planes mainly trend northwest, and east-west, and locally to the northeast. Recumbent folds usually are associated with the thrust structures.

The Laizishan dome is 25 km long and 12 km wide and trends to the north-northeast (fig. 3-13). Total thickness of the calcareous Paleozoic strata in the core is about 1,300 m. Triassic strata mainly are exposed on the east and west limbs of the fold. The west limb consists of platform carbonate rocks, while fine-grained clastic rocks, formed in shelf-chasm facies, are present on the east limb. Total thickness of these strata is about 1,000 m. The two limbs of this fold are asymmetric; the dip angle of the eastern limb is around 20° to 40° E, and is 5° to 20° W on the western limb. Well-developed, arc-shaped faults surround the anticline and often are associated with Au, As, Hg and Sb mineral occurrences or deposits (fig. 3-13).

The Banchang thrust is located 3 km northeast of the Lannigou Au deposit, along a line from Baiceng to Banchang and Pingbu (not noted on figures). It is about 60 km long and 1 to 13 km wide, and consists of four parts: (1) the front fold zone; (2) an upper nappe system; (3) a lower nappe system; and (4) a thrust detachment zone (Chen, Y.M., 1992). The associated 30– to 100–m-wide fault zone is filled with l siliceous breccia, mud- and clay-rich gouge, and oval-shaped structural lenses (phacoids). Minimum horizontal movement of this structure is 1.5 km, with about 800–m-long vertical displacement. Direction of thrusting was from northeast to southwest with a sinistral shear component. The Lannigou Au deposit is located on the western

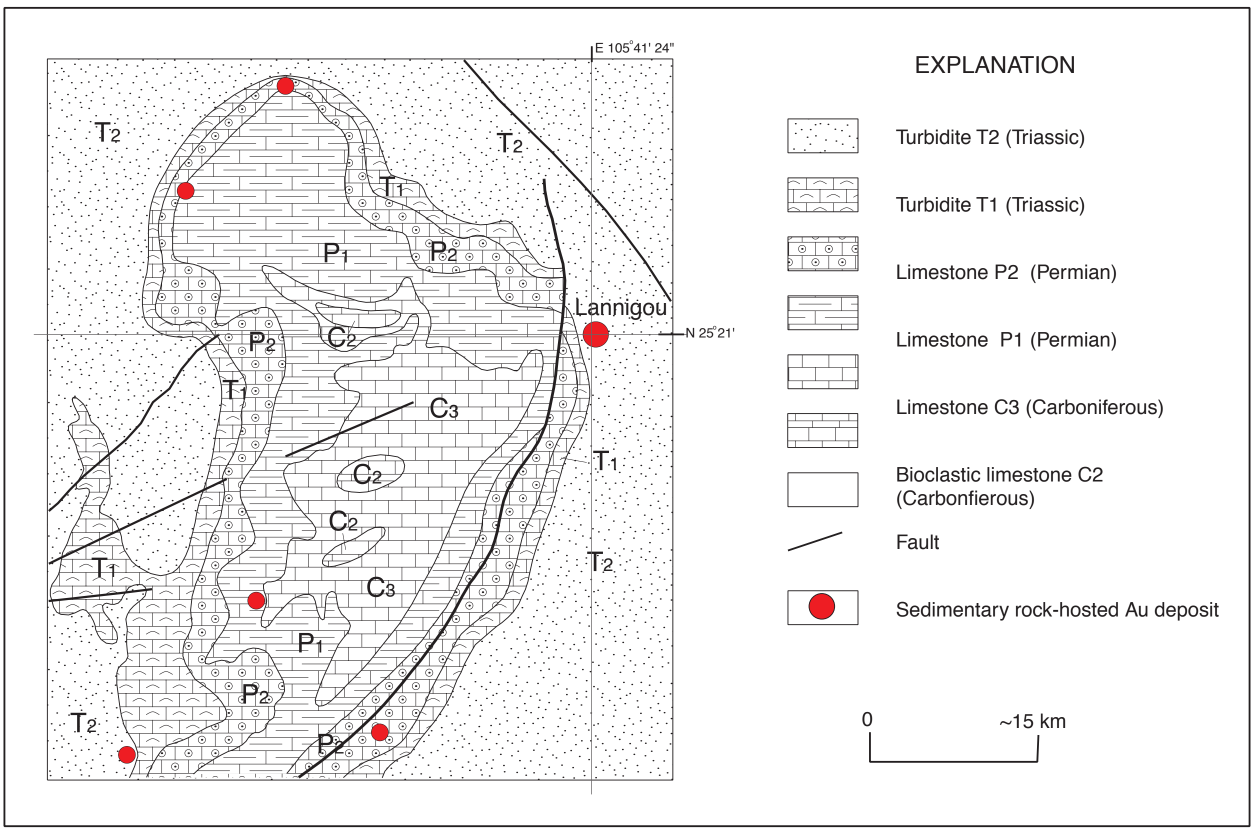

Figure 3-13. Geology of the Lannigou Au deposit area showing the structural control of the Laizishan dome. The ore deposit is localized along the Permian-Triassic boundary at the edge of the dome, Guizhou Province, Dian-Qian-Gui area.

side of the Banchang thrust structure at a protruding, nose-like part of the eastern limb of the Laizishan dome (figs. 3-1, 3-13). Structures proximal to the orebody are similar to the regional structural grain and therefore the two main structures are north-south-trending in the western part of the district, while northwest-trending structures are present in the eastern part of the district. Another two sets of structures, trending west-northwest and northeast, are present in the central part of the district (fig. 3-15).

Different lode orientations, and alteration and breccia types in separate fault zones in the Lannigou Au deposit area control distribution and tenor of Au in the orebodies. The No. 1 orebody, host of most of the Au reserve in the deposit, is controlled by the F_3 fault, the most important host-structure in the Huangchanggou block (fig. 3-15). The F_2 fault controls the No. 2 orebody and the north-northwest-striking F_{11} fault in the Chenban block, and the northwest-striking F_{14} fault in the Lintan block, also are important ore-control structures (fig. 3-15).

North-south-striking structures, such as the F_1, F_7, and F_9 faults in the western part of the Lannigou Au district (fig. 3-15) are interpreted by Luo, X.H., (1994) as compressional components of the thrust structure. Of these, the 8,000–m-long, 5–m-wide F_1 fault, the largest fault crossing the district, dips west at low to medium angles and is filled with well-developed tectonite, Au and alteration minerals. The 3,000–m-long F_7 fault also contains strong alteration

Figure 3-14. Photographs of mine area of the Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area. (*A*) Looking northwest up the No. 1 orebody. Central disturbed zone has been selectively mined. (*B*) Exploration adit on the No. 2 orebody. Note soil profile.

and mineralization (fig. 3-15). Northwest-trending structures include the Lannigou syncline, the Lintan anticline, and the F_{14}, F_5, F_4, and F_{11} faults that were formed by lateral northeast-southwest compression (Lou, X.H., 1994).

The axial plane of folds ranges between 200 and 3,500 m long, and the folds are between 400 and 1,000 m wide. All folds have gentle-dipping southwest limbs and steep-dipping northeast limbs. The core of the Lintan anticline (fig. 3-15) consists of the third sequence of Xinyuan Formation rocks, while rocks of the Bianyang Formation are exposed in the core of the Lannigou syncline (figs. 3-13, 3-15). The mineralized, 4,000–m-long F_{14} fault is coplanar with the axial plane of the Lintan anticline and dips 60∞ northeast. The Au mineralized zone along the F_{14} fault is about 200 m long, 2 to 3 m thick, containing high-grade Au concentrations of up to 30 g/t Au. The north-northwest-striking 4– to 10–m-wide F_{11} fault dips 55° to 75° northeast and is associated with strong silicification and pyritization along a 300–m-long zone (fig. 3-15). Other northwest-striking faults contain only weak alteration.

Northeast-striking structures comprise a group of shear zones, which include the ore-bearing, 500–m-long, 5–m-wide F_2 and F_{10} faults (fig. 3-15). The F_2 fault dips 45° to 80° southwest and contains numerous round, tectonic, phacoidal lenses and is host for the 270–m-long No. 2 orebody, which has the thickest and highest Au grades at the intersection of the F_2 and F_3 faults (fig. 3-16).

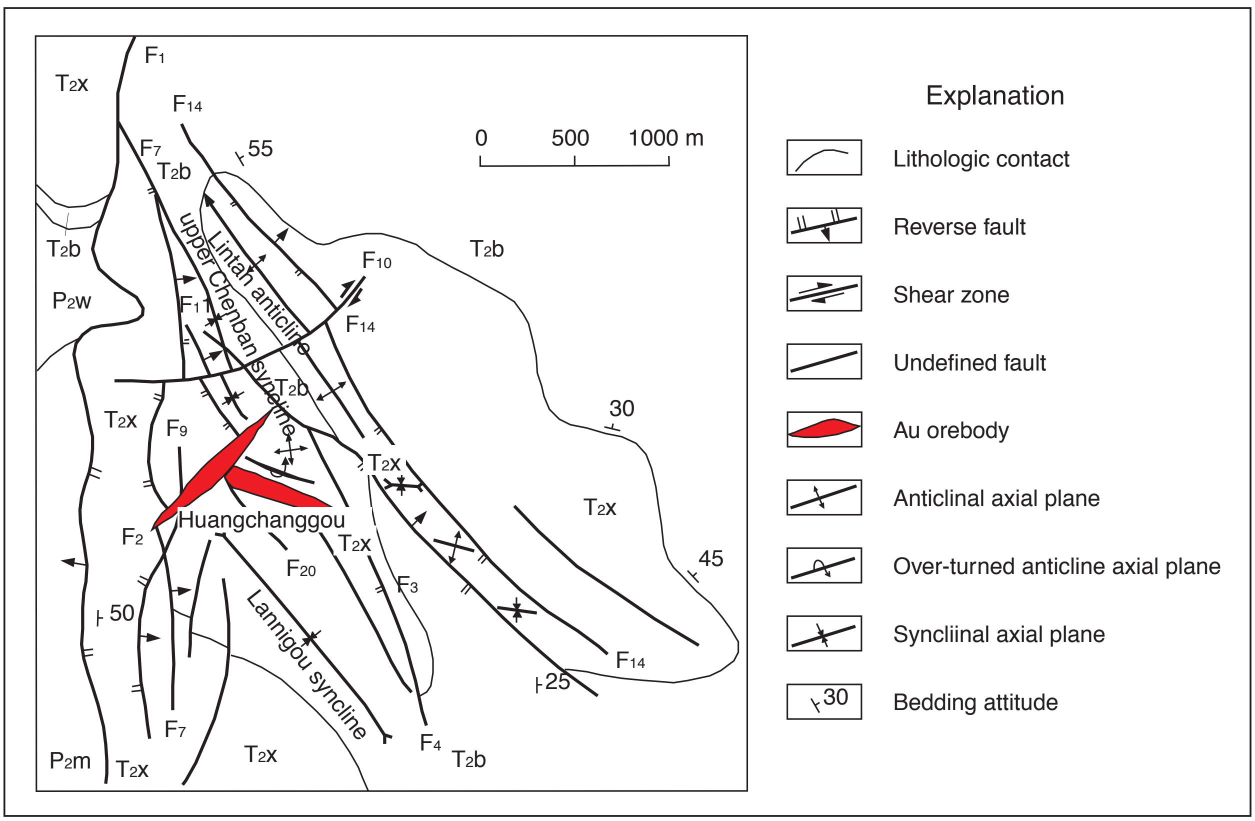

Figure 3-15. Geological map of the Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area. T2b - Bianyang group; T2x - Xinyuan group; T1l - Luolou Formation; P2w - Wujiaping Formation; P1m - Maokou Formation. From Lou, X.H., (1994). See fig. 3-1 for latitude and longitude.

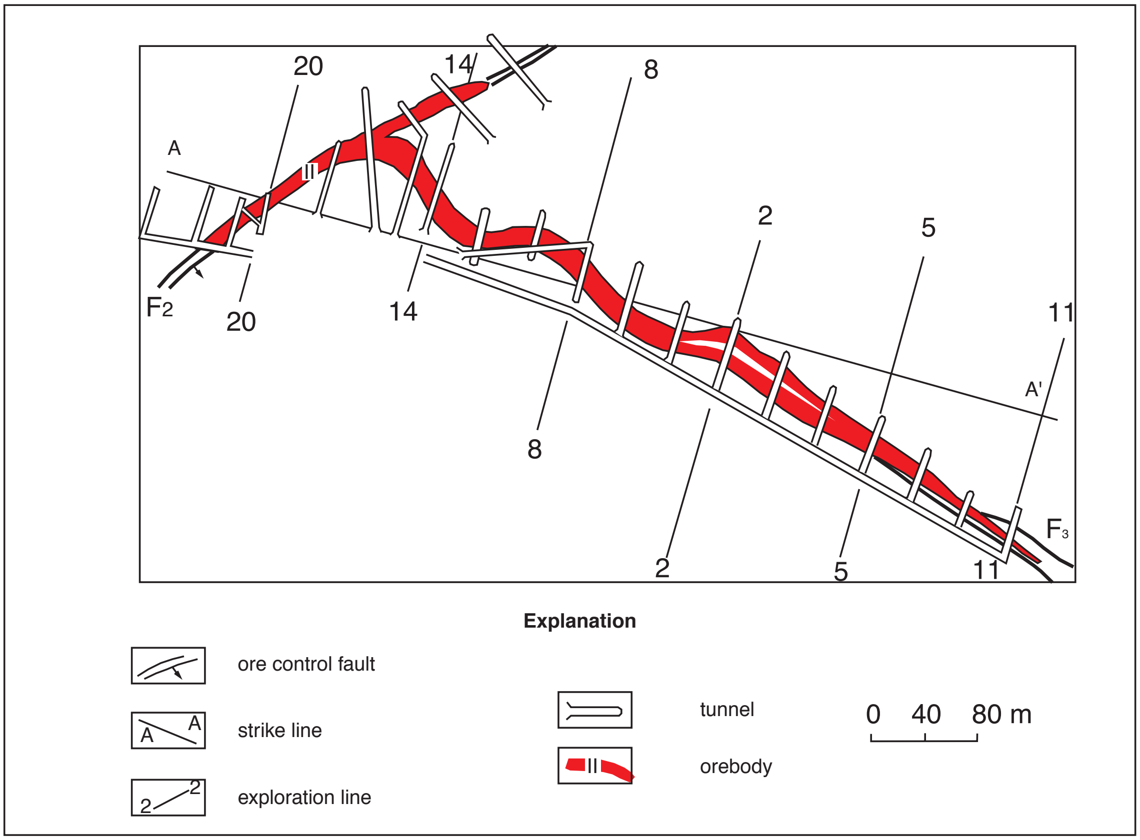

Figure 3-16. 4th level map (600 m) of the Huangchanggou block in the Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area, showing the orebodies at the intersection of the F2 and F3 faults. From Luo, X. H. (1994).

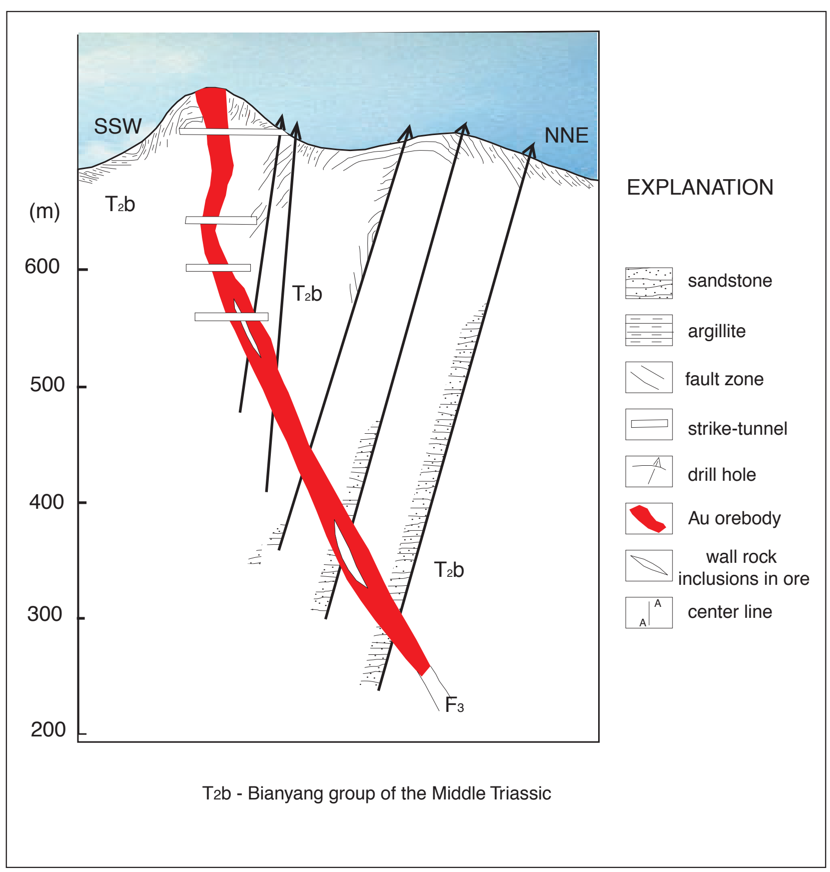

Figure 3-17. Geologic cross section through the Huang-Chang block in the Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area, showing the curving with depth along the F3 fault into an S-shape.

West-northwest-striking faults are well developed in the Huangchanggou block (fig. 3-15), and also are present in the northern end of the district. The 700–m-long F_3 fault, trends 290° and dips 55° to 85° northeast, with a drill-indicated depth of 570 m. The F_3 fault has an "S"-shape both in horizontal and vertical planes (figs. 3-16 and 3-17). The F_3 fault is an intensely strained structural deformation zone, as well as a strong mineralized zone. Both boundaries of this strained zone (fault plane) are similar. The width of the fault zone is about 8 to 20 m, maximum up to 30 m wide, and varies along both strike and dip. Structural interpretation of the F_3 fault by Lou X.H. (1994) suggests an evolutionary history of multiple compressional movement and deformation from sinistral shearing, thrusting, and dextral sliding, to extension and south-north compression. Many of these events are interpreted to have been broadly coeval with Au deposition.

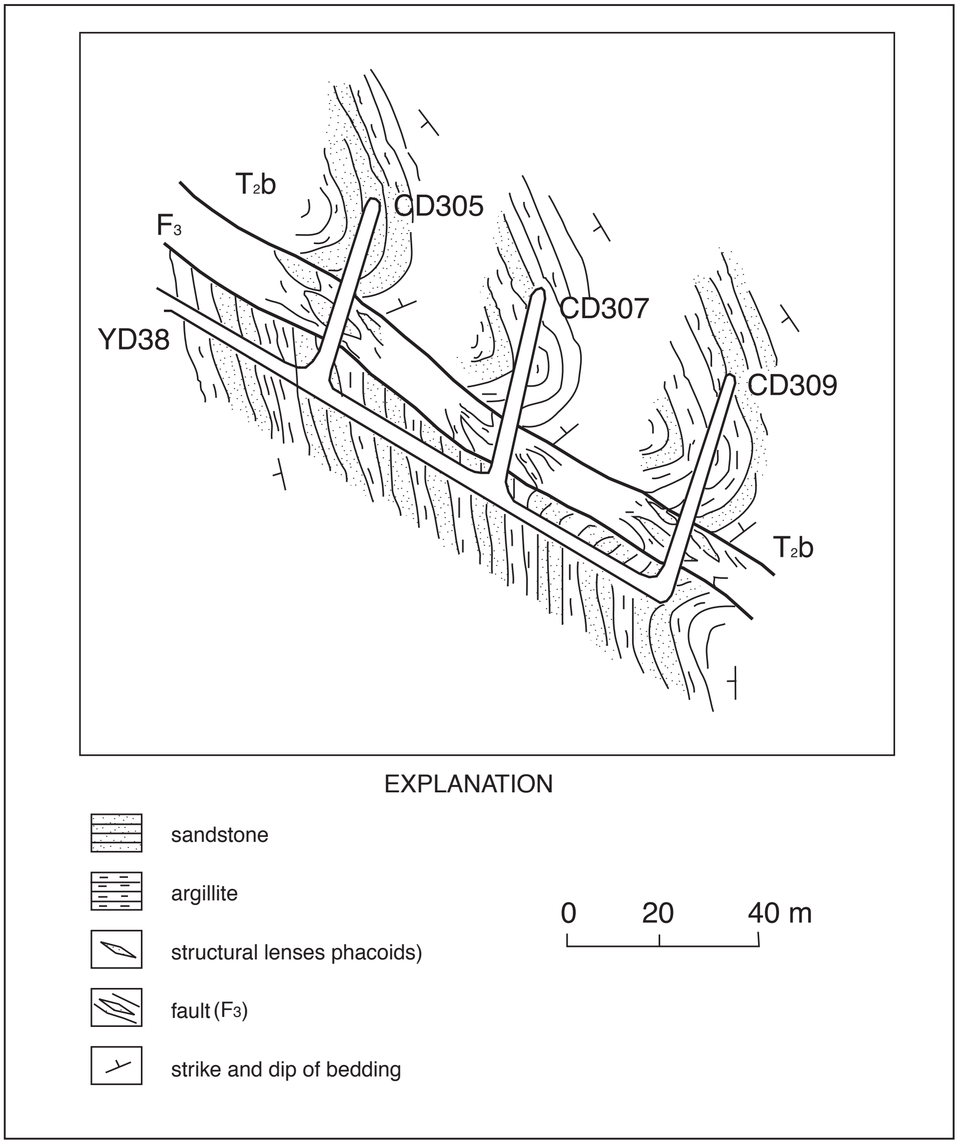

Figure 3-18. Part of 3rd level map (640 m) of the Huangchanggou block in the Lannigou Au deposit, showing deformation zone along orebody. T2b - Bianyang group of middle Triassic: YD38 - strike-tunnel; CD307 - cross tunnel.

Rocks in the F_3 shear zone contain tensional breccia, compressional cataclastic rocks, and mylonite (figs. 3-18, 3-19, and 3-20). Competent rocks, such as sandstone, were deformed into lenses or en echelon phacoidal bodies, while soft rocks, such as argillite, became foliated phyllonite, and clay-rich gouge that also fill fractures in phacoidal lenses, or wraps around them. Breccia types are similar to those found in Carlin-type deposits in Nevada (Peters and others, 1997) and the phacoidal textures are very similar to those described in the large Betze orebody by Peters and others (1998) and Peters (2000a,b) along the Carlin trend, Nevada. Size of the phacoidal sandstone lenses is dependent upon the bedding thickness of the original rocks and varies from several centimeters to 1 meter; the maximum long axis is about 3 to 4 m. These structural lenses have medium roundness and a smooth surface. Many small drag folds also are present in the strata, and in general, drag synclines are present in the hanging wall, while the drag anticlines are present in the footwall (fig. 3-21). These textures have many similarities to shear folding fabrics documented in the Betze orebody by Peters and others (1998, 2000). Intensely strained, small, fragmental cataclastic rocks usually are associated with high-grade Au orebodies, while large-fragmental cataclastic rocks are present in lower grade Au orebody blocks. Gold grade in the No. 1 orebody also is related to thin- to medium-bedded, fine-grained sandstone, siltstone and argillite (fig. 3-21).

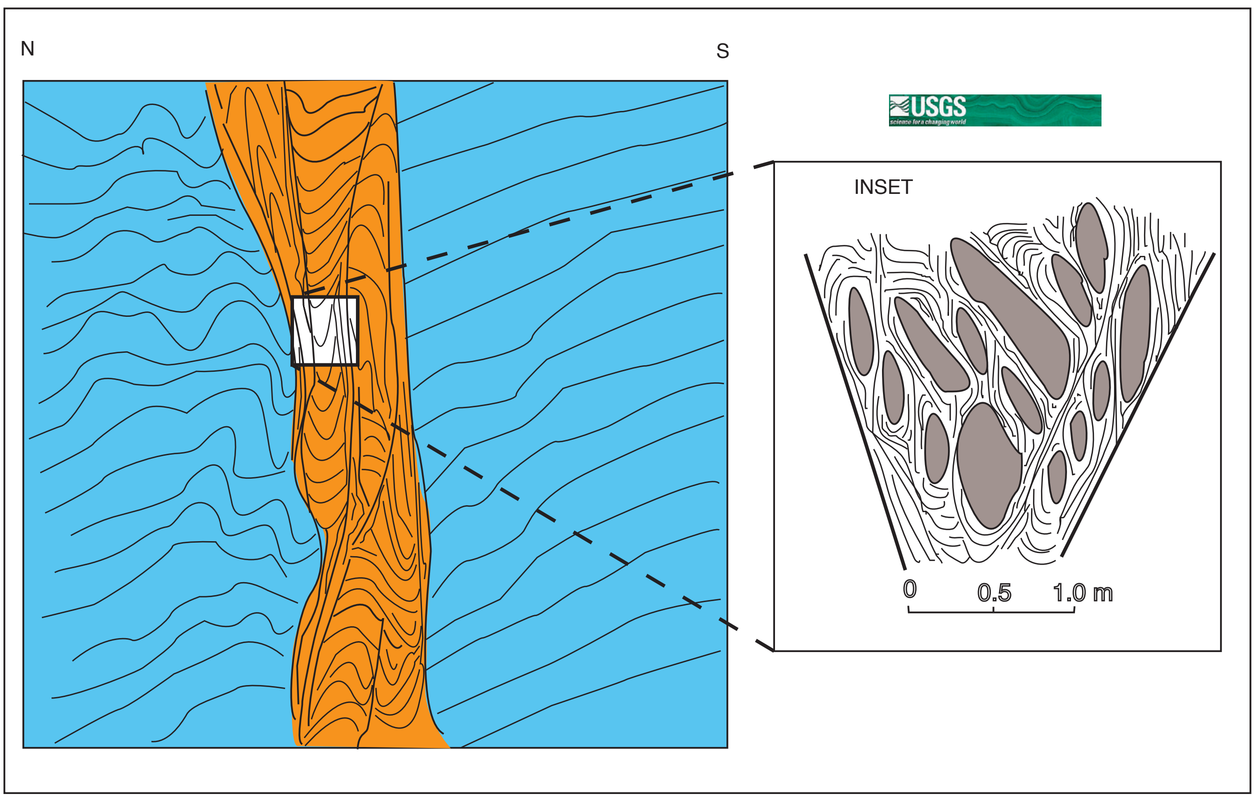

Figure 3-19. Schematic sketches of phacoid development along Main No. 1 shear zone (F3 fault) in the Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area. Shear zone is up to 100 m wide and contains distorted, deformed, attenuated, folded bedding. Bedding external to the shear zone is folded and deformed on the northern side. Inside the shear zone, the rock is dismembered and local phyllonitic seams and clay-gouge seams surround local phacoidal shapes (inset from Luo, X.H., 1994). This is the same zone shown in Figure 3-14A.

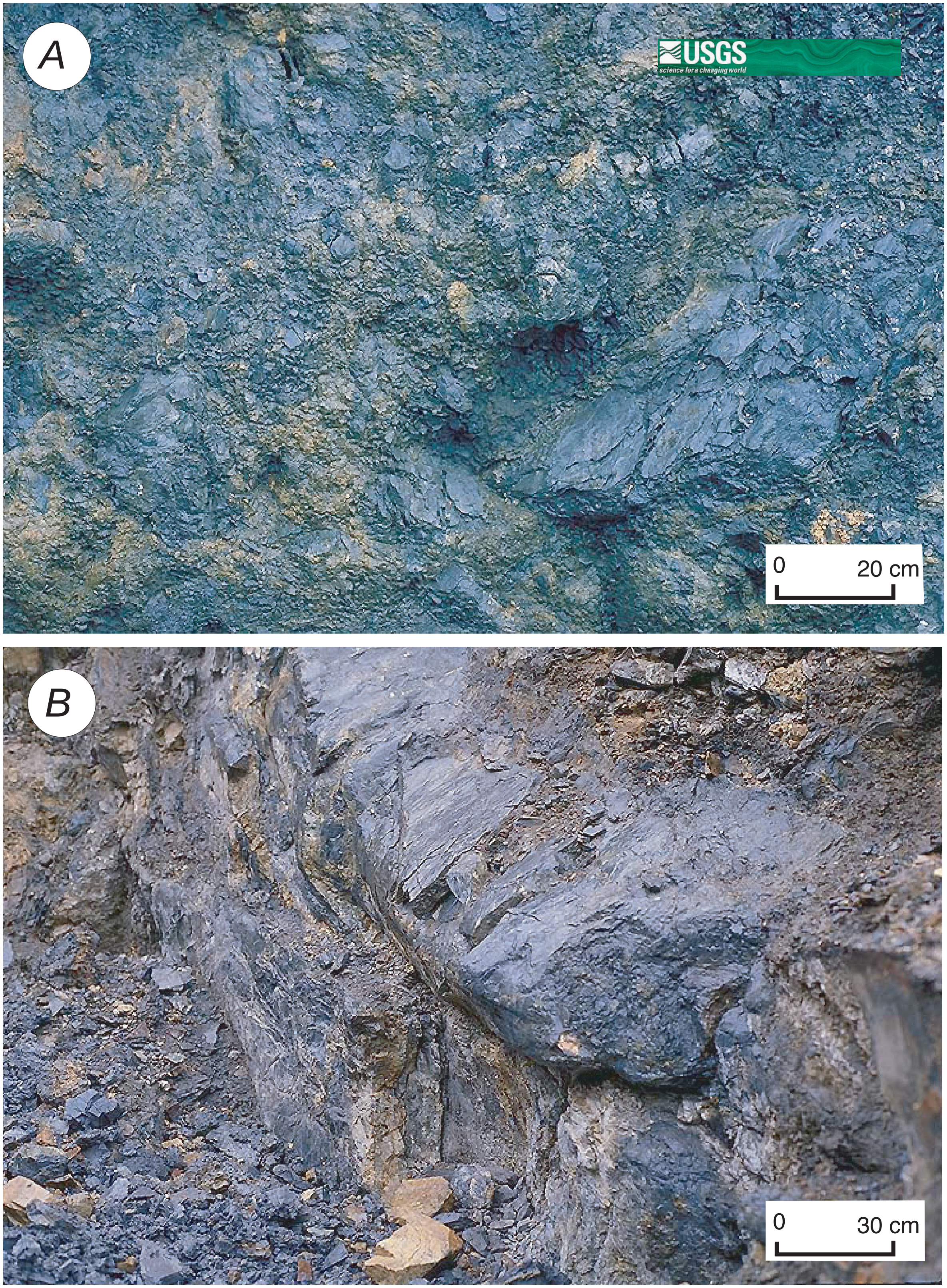

Figure 3-20. Deformation textures in Au ores from the No. 1 shear zone, Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area. (*A*) Carbonaceous gouge and phyllonite in shaley zone. (*B*) Deformation of carbonaceous material.

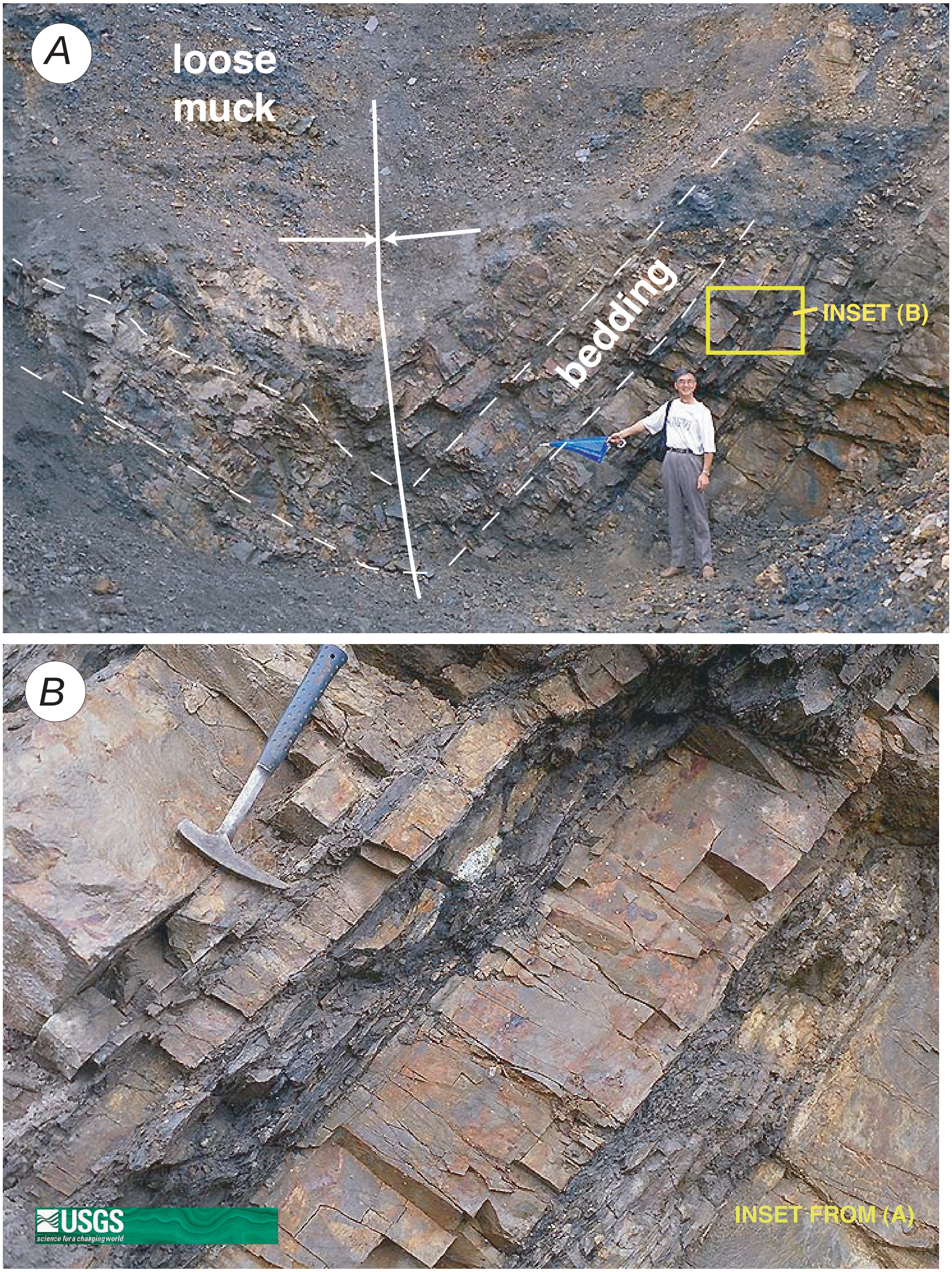

Figure 3-21. Photographs of synclinal folding in turbiditic Triassic sedimentary rocks proximal to the No. 1 shear zone, Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area. (*A*) Synclinal folding of sandstone layers and shaley interbeds. (*B*) Enlargement of layered bedding from inset. Trace and economic Au contents lie in the darker, carbonaceous shale beds.

Alteration at the Lannigou Au deposit is present in and around the Au orebodies as wide zones that are distributed along and within host fault zones. Silicification, carbonatization, and argillitization are the most significant alteration types and locally are accompanied by cinnabar, orpiment, and realgar. Three periods of silicification are identified in the deposit: (1) earliest silica consisting of fine-grained quartz, present as veinlets often associated with pyrite, arsenopyrite, carbonate, and illite; (2) second-stage network silica, made up of 1–mm-wide quartz veinlets that co-exist with significant pyrite, arsenopyrite, carbonate, and illite (fig. 3-22); and (3) late-stage silicification present as coarse-grained quartz coexisting with calcite, orpiment (realgar), cinnabar, stibnite, and lesser sphalerite. Carbonatization includes the introduction of dolomite, ankerite, and calcite. Dolomite usually precedes calcite, which is associated with cinnabar, stibnite, orpiment, and realgar. Argillization is largely illite or illite-quartz veinlets usually associated with pyrite and arsenopyrite (fig. 3-22). These paragenetic and alteration assemblages are similar to Carlin-type deposits in Nevada (Arehart and others, 1993; Arehart, 1996; Ferdock and others, 1997; Hofstra and Cline, 2000).

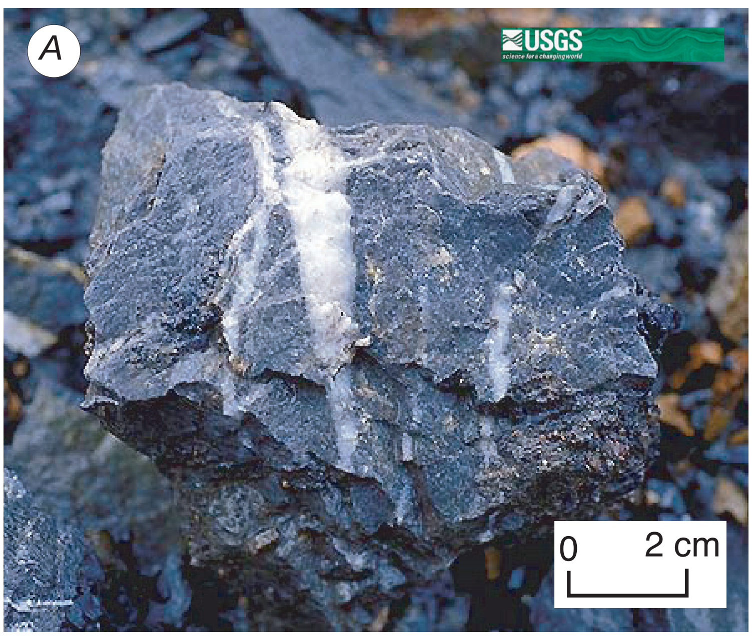

Figure 3-22. Photographs of Au ore specimens with quartz veins in competent sandstones in the Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area. (*A*) Fist-sized specimen in ore pile. (*B*) Slabbed specimen with network veinlets. Note sericite and clay alteration near veinlets.

Ore minerals are disseminated through the Lannigou Au deposit, but also are present in veinlets. Sulfide ore minerals form about 4 volume percent of the ores; of these, pyrite forms about 80 volume percent of the ore minerals. Pyrite, cinnabar, and orpiment (realgar) often are present in the ore with euhedral, sub-euhedral, and granular textures. The margins of pyrite are often altered into a girdle-band texture by As-rich (Au-bearing?) pyrite (fig. 3-23). Early pyrite usually has a cataclastic texture. Some of these ore minerals also are disseminated in the ore as xenomorphic grains. In addition, As–Ni, and Fe–, Ni–, Co–, Zn–, As–sulfide minerals, was well as, Hg-rich sphalerite locally are present (figs. 3-23, 3-24, 3-25). Similar polymetallic sulfide minerals are reported in the Betze deposit in Nevada by Peters and others (1998, 2000). Gangue minerals in the Lannigou Au deposit consist of quartz, clay, and carbonate minerals. Poikilitic textures are formed by clay minerals and quartz enclosing the ore minerals.

Hydrothermal quartz and pyrite are the most common minerals in the Lannigou Au deposit. Hydrothermal quartz usually is present in intersecting veins and veinlets that commonly contain cataclastic or rock flour fault rocks. Quartz often has undulatory extinction and encloses sulfide minerals. Pyrite usually is present as fine-grained, xenomorphic grains, or as idiomorphic

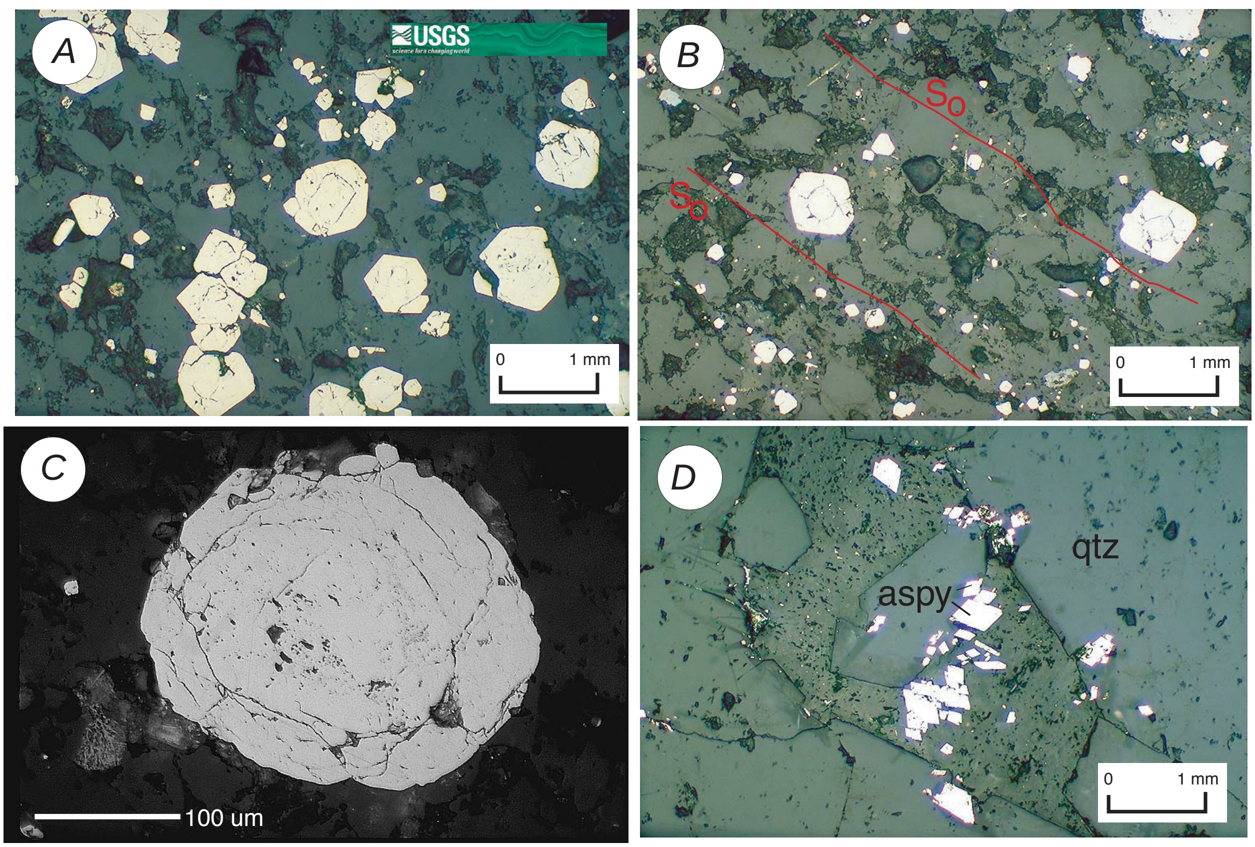

Figure 3-23. Microphotograph of pyritic Au ores in the Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area. (*A*) Zoned (“strawberry”) pyrite with As-poor cores and As-rich rims in a matrix of detrital quartz and illite in sandstone. (*B*) Disseminated Au-rich pyrite of different sizes. Larger grains have As-pore core. Some smaller grains may be oriented along bedding-So. (*C*) SEM back scatter image of strawberry arsenically-zoned pyrite grain. Arsenic content is not high in this grain as indicated by the lack of brightness contrast, although the growth texture is evident. (*D*) Arsenopyrite associated with inclusion in quartz vein.

crystals with pentagonal dodecahedron, octahedron and cubic crystals that often appear to as girdle-bands in microscopic view. Arsenopyrite is another important Au-host mineral; its euhedral crystals, which form needles and prisms, characterize it. Additionally, ankerite and calcite often co-existed with the Au-host minerals of pyrite and arsenopyrite.

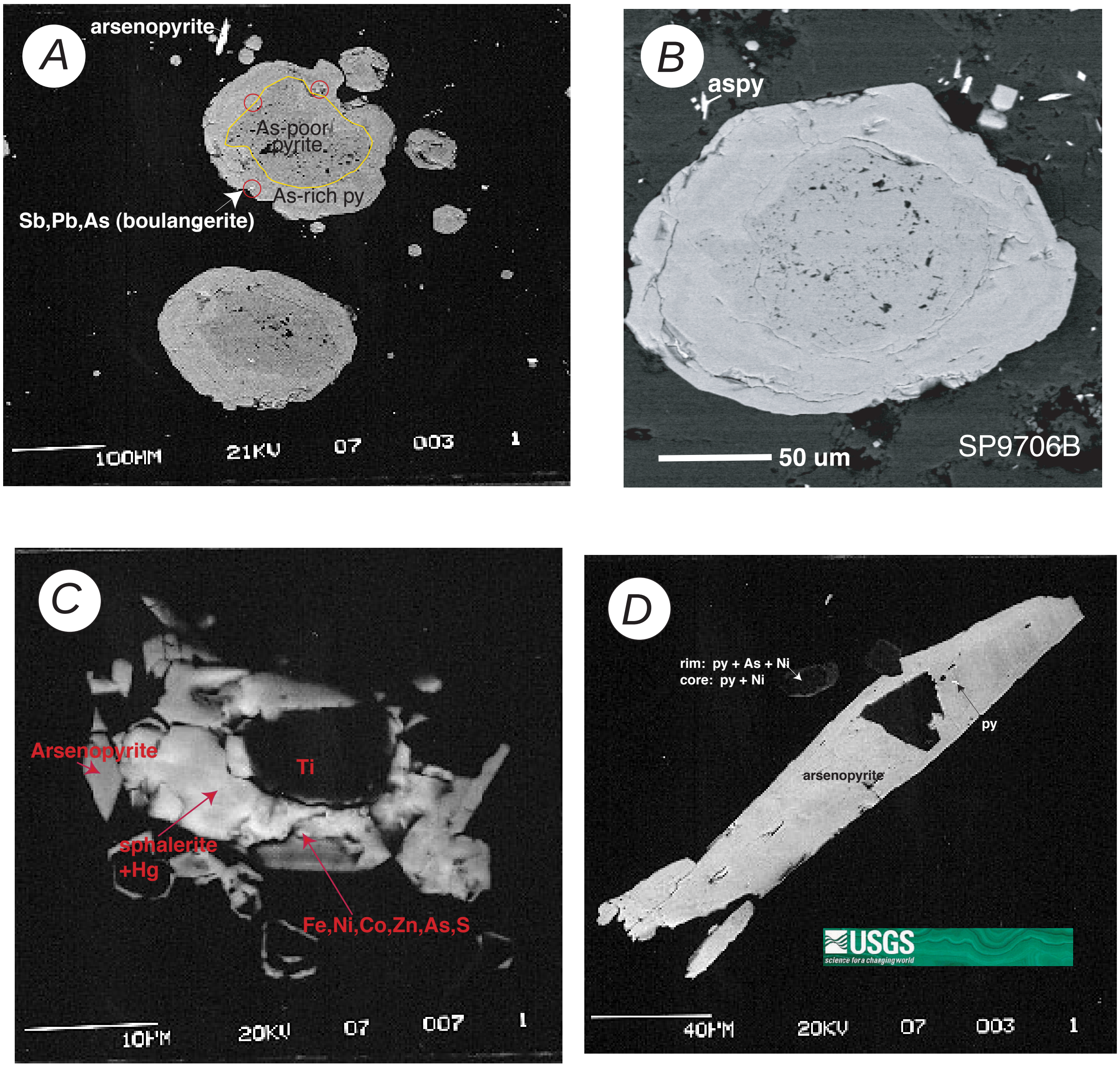

Figure 3-24. Scanning electron microscope (SEM) back scatter images of sulfide grains in the Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area. (*A*) Zoned pyrite grains with older As-poor cores and outer growth rims of As-rich pyrite (noted by yellow line). Boulangerite inclusions are present along growth rims as <10 micron-size dots. Arsenopyrite also is present as euhedral grains surrounding pyrite. (*B*) Enlargement of arsenically-zoned pyrite grain showing texture and complexity of As-rich outer rims. The grain also contains small boulangerite inclusions. (*C*) Complex polymetallic sulfide grain containing mixtures of Fe, As, Zn, Hg, and Ni (Co) sulfide grains. (*D*) Skeletal arsenopyrite grain with small pyrite inclusions. Peripheral rounded grains contain Fe, As, and Ni sulfides with As-rich rims.

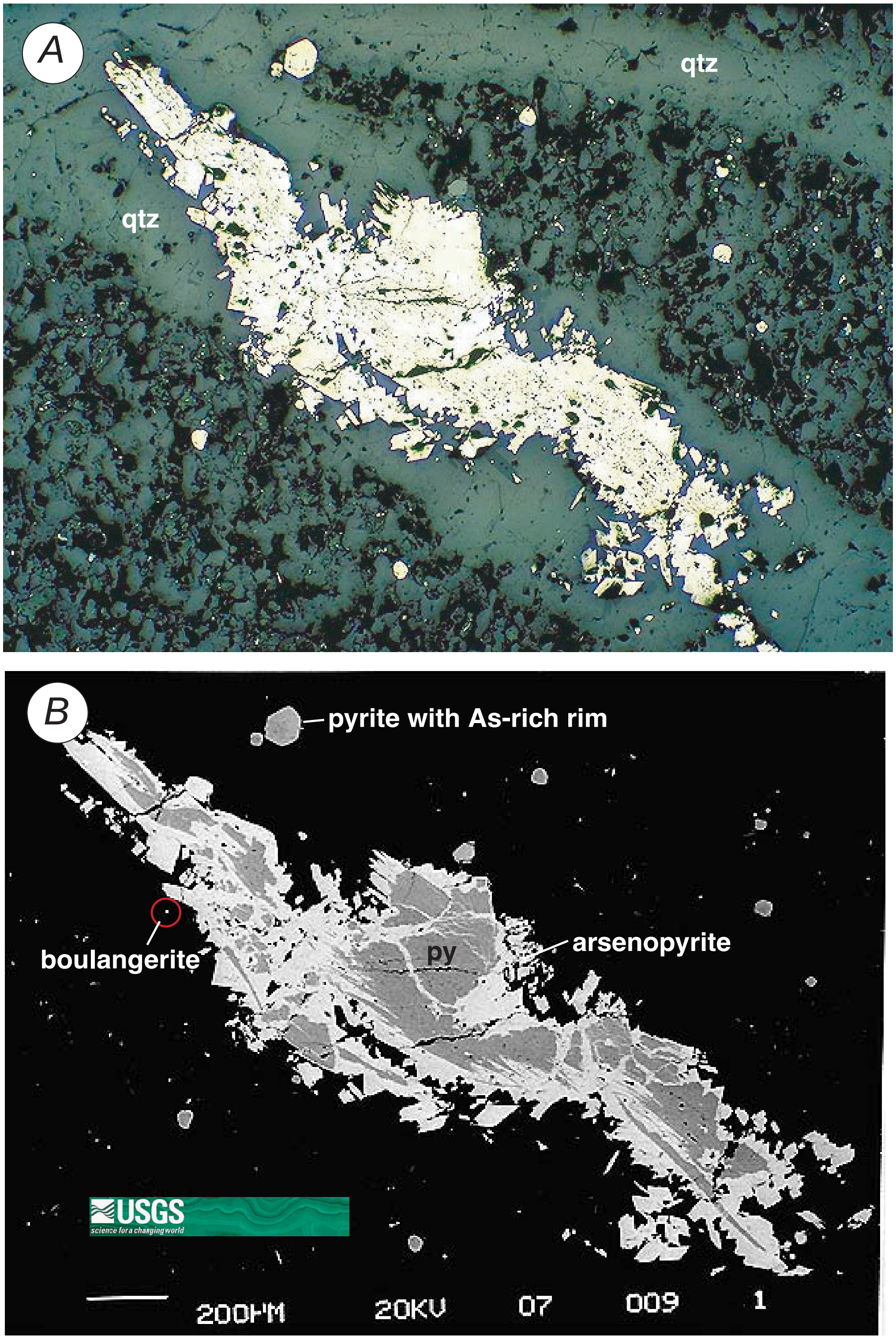

Figure 3-25. Photographs of a composite pyrite and arsenopyrite grain in a quartz veinlet, Lannigou Au deposit, Guizhou Province, Dian-Qian-Gui area. (*A*) Polished thin section, showing outline of quartz veinlet. (*B*) SEM back scatter image of grain shown in A. Arsenopyrite and pyrite are intergrown. Arsenical pyrite is disseminated nearby in wall rock. Boulangerite also is disseminated near the grain (shown in red circle).

Hydrothermally generated pyrite and As-rich pyrite are important Au-hosting minerals. Gold assays of up to 123.05 g/t Au are present in pure pyrite samples. However, not all pyrites contain Au, on the basis of SEM and TEM analyses, and observations of crystal morphology and size (Luo, X.H, 1994). Part of the No. 1 orebody contains less Au in areas consisting mostly of pyrite; however, other parts of the orebody contain combinations of pyrite, orpiment, realgar, cinnabar, and stibnite and contain high Au concentrations. Pure cinnabar contains less Au, whereas pure orpiment, realgar, and stibnite contain almost no Au. This indicates that Au-bearing arsenical pyrite was formed before, but during the same mineralizing event, as cinnabar, orpiment, realgar, and stibnite (see also, Woitsekhowskaya and Peters, 1998; Peters and others, 1998, 2000).

Because Au is predominantly related to As-bearing pyrite, Au assays have a positive relation to the As content in the pyrite. Growth zoning of As-rich pyrite grains contain micron-scale zoning bands and small inclusions of boulangerite (fig. 3-24). Most As-bearing pyrites have girdle-banded textures that contain a number of morphological crystal shapes such as pentagonal, dodecahedal, octahedral, cubic, and round granular shapes. Grains of euhedral and subhedral 0.005– to 0.074–mm-sized arsenopyrite are common and locally host Au (fig. 3-25).

Geochemically, the Lannigou Au deposit has similarities to other Carlin-type deposits in the Dian-Qian-Gui and Qinling fold belt areas in China and to many Carlin-type deposits in Nevada (Appendix IV). The geochemical characteristics are elevated to anomalous concentrations of As, Hg, and moderate concentrations of Cu, Zn, Ni and Tl. Antimony usually is low in the ores in the Lannigou Au deposit. The No. 1 orebody contains geochemically anomalous concentrations of As, Hg, and C (Luo, X.H., 1994). Their amounts in the ore are As = 0.12 to 1.10 weight percent (average 0.53 weight percent), Hg = 10 to 1,000 ppm (average 108 ppm), and C = 1 to 2 weight percent (average 1.55 weight percent). Arsenic, Hg, and C are unevenly distributed in the orebody. As and Hg are concentrated in local ore blocks, in which the amount of As and Hg is three times higher than the average of the whole orebody. Carbon mainly is enriched near the hanging wall and footwall and decreases in the center.

Banqi Au Deposit

The Banqi Au deposit, in Ceheng County, Guizhou Province, is approximately 24 km southwesterly, in a 225° direction, from the Ceheng County Town at 105°36'15" to 38'50" E, and 24°44'04" N (fig. 3-1). Orebodies mainly are located in Upper Paleozoic and Lower Mesozoic rocks at the southern margin of the Banna dome (fig. 3-26). The No. 0 and No.1 orebodies dip 30 to 40° southwest and are 0.5 to19.76 m thick, and over 100 m long, and have been explored >300 m deep. The grade is 1.20 to 20.68 g/t Au (average 5.01 g/t Au). Grades generally are about 1 g/t Au, but extend up to 80 g/t Au. The deposit was not visited as part of this study and therefore descriptions are modified from Pu, Hanke (1987), Xu E.S. and others (1992), and Liu, D.S. (1994).

Sedimentary strata exposed around the Banna dome in the Banqi Au deposit area are the Lower Permian Maokou Formation (P_1m), Upper Permian Wujiaping-Changxing Formation (P_2w-c), Lower Triassic Ziyun Formation (T_1z), and the Middle Triassic Xinyan (also Luolou Formation of Xu and others, 1992) (T_2x) and Bianyang (T_2b) Formations (fig. 3-26). The Maokou Formation (P_1m) consists of light-colored, thick-bedded, massive limestone with local chert nodules. The Upper Permian rocks include mudstone, interbedded tuff horizons, reef limestone, breccia, and siliciclastic rocks. Unit P_2w-c is composed of reef limestone. Lower Triassic rocks include: (1) thin-bedded limestone, clay-rich limestone, gray-green shale, basal yellow-brown shale in the lower member; (2) claystone, brecciated claystone, and sandy breccia, which is host for ore, and (3) unit T_1z, the 26.24-m-thick upper member, composed of breccia-bearing argillite, and silty fine-grained sandstone. Gold mainly is hosted in this upper member. Horizons of the lower member composed of rudaceous limestone, bioclastic limestone contain local strong silicification together with stibnite. Units T_2x and T_2b consist of siltstone and fine-grained sandstone. Two lithologies are favorable for Au mineralization: (1) carbonaceous clay-siltstone, and tuffaceous rocks, and (2) impure limestone and dolomitic limestone. Host rocks are highly fractured and brecciated. Igneous rocks are present as small diabase, granite, and quartz-porphyry dikes (Xu, E.S., and others, 1992).

The Banqi Au deposit lies in an east-west-trending compression belt of linear folds and domes. The Au orebodies are present along the south limb of the east-west-elongated Banna dome (fig. 3-26). The dome is 6.5 km long and 4.5 km wide and the limbs dip steeply at the margins of the dome, such that strata in the south side are locally overturned. Faults are east-west-striking, vertical zones along the southern margins of the Banna dome (fig. 3-26), especially along the Permian-Triassic contact. Faults also are present along disconformities in the stratigraphic section. For example, the F_1 fault is an interformational shear zone that strikes east-west and dips 45 to 50° south. Gold orebodies mainly are present in silty fine-grained sandstone horizons of the T_1z unit below the F_1 fault surface and above an unconformable zone of dissolution and karst.

Alteration at the Banqi Au deposit consists of silicification, introduction of sericite-clay minerals, pyrite, arsenopyrite, realgar, and carbon. Ore minerals mainly are pyrite, marcasite, arsenopyrite, realgar, and stibnite. As well as chalcopyrite, sphalerite, and galena. Gold is present as native Au that is disseminated in micron-scale grains, usually in sulfide minerals, and also in sericite, clay, and carbonaceous minerals. Gangue minerals are quartz, calcite, barite,

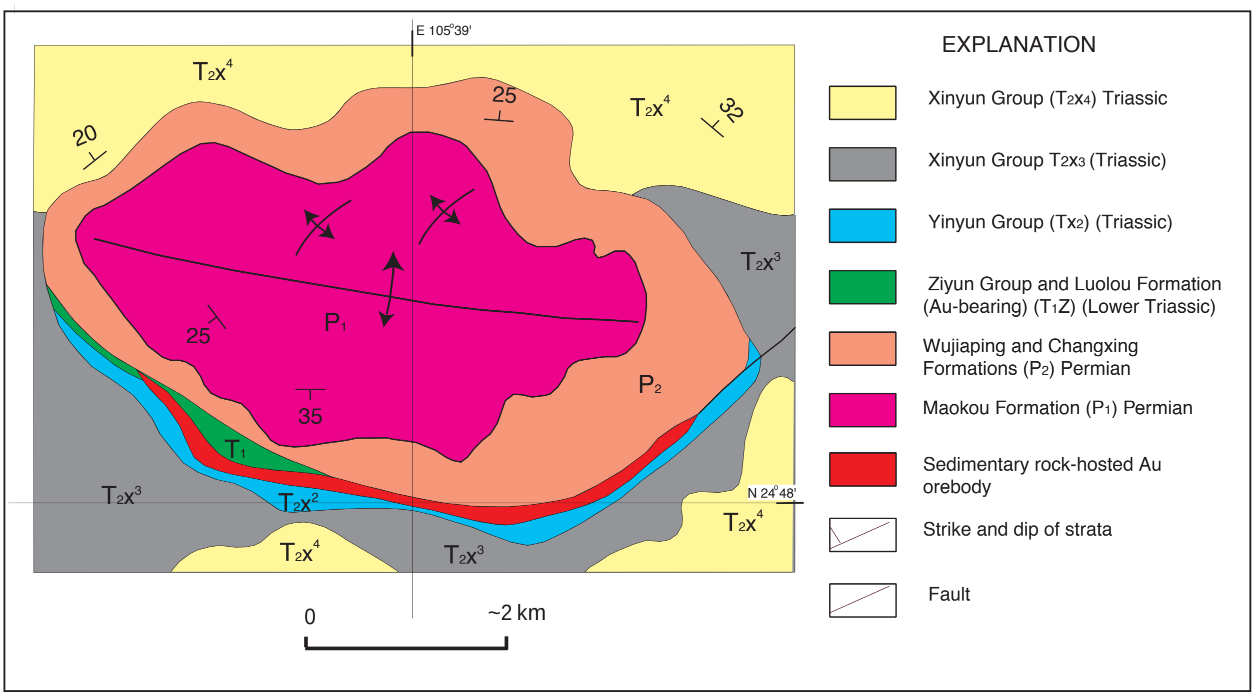

Figure 3-26. Geologic map of the Banqi Au deposit, Guizhou Province, Dian-Qian-Gui area showing the short-axial anticline structure that controls ore. Modified from Pu, Hanke (1987) transferring from Liu, D.S. (1994). Latitude and longitude approximate.

gypsum, dickite, fluorite, and hydromica. These ore and gangue minerals are similar to those found in the larger Lannigou Au deposit.

Geochemically, Au is associated with As. When As is between 600 and 1,000 ppm, Au generally is high; however, when As is >2,000 ppm, Au has lower values in the ore (Xu E.S. and others, 1992). This relation is similar to those found among Nevada Carlin-type deposits, where realgar-orpiment ores are paragenetically late and contain Au mostly in assimilated pre-realgar arsenical pyrite (see also, Ferdock and others, 1998; Peters and others, 1998, 2000; Woitsekhowskaya and Peters, 1998).

Yata Au Deposit

The Yata Au deposit is situated in Ceheng County, Guizhou Province in a southwest direction of 245°, 17 km away from the Ceheng County town at 105° 38'45" E, 24° 54'25" N. The Yata Au Mining District is an east-west-trending, 1,800–m-long 1,000–m-wide zone composed of more than 20 orebodies. The individual orebodies are tabular, 100 to 500 m long, 2 to 8 m thick, and extend 20 to 300 m deep (fig. 3-27). The average grade is 5.09 g/t Au. The deposit is of medium size (<100 tonnes Au). The deposit was not visited as part of this study and information is from that compiled in Li, Z.P. and Peters (1998).

The main host stratigraphic horizon is the No. 2 member of the Middle Triassic Ximan Formation (T_2x^2), which is composed of interbedded sandstone, fine-grained sandstone, siltstone, and argillite.

Regionally, the Yata Au deposit is located in an east-west-striking structure zone that contains complex folds and high-angle, strike-slip faults. The Au deposit lies along the south limb of the 3–km-long, east-west-striking Huangchang anticline. Limbs of the anticline dip at angles between 35 and 75° and contain chevron folds and mesoscopic compressive fracture zones. The main strike slip faults, F_1, F_2, F_3, and F_6 (not shown on fig. 3-27) contain compression-shearing fabrics and control the overall Yata Au belt and the Yata Au orebody.

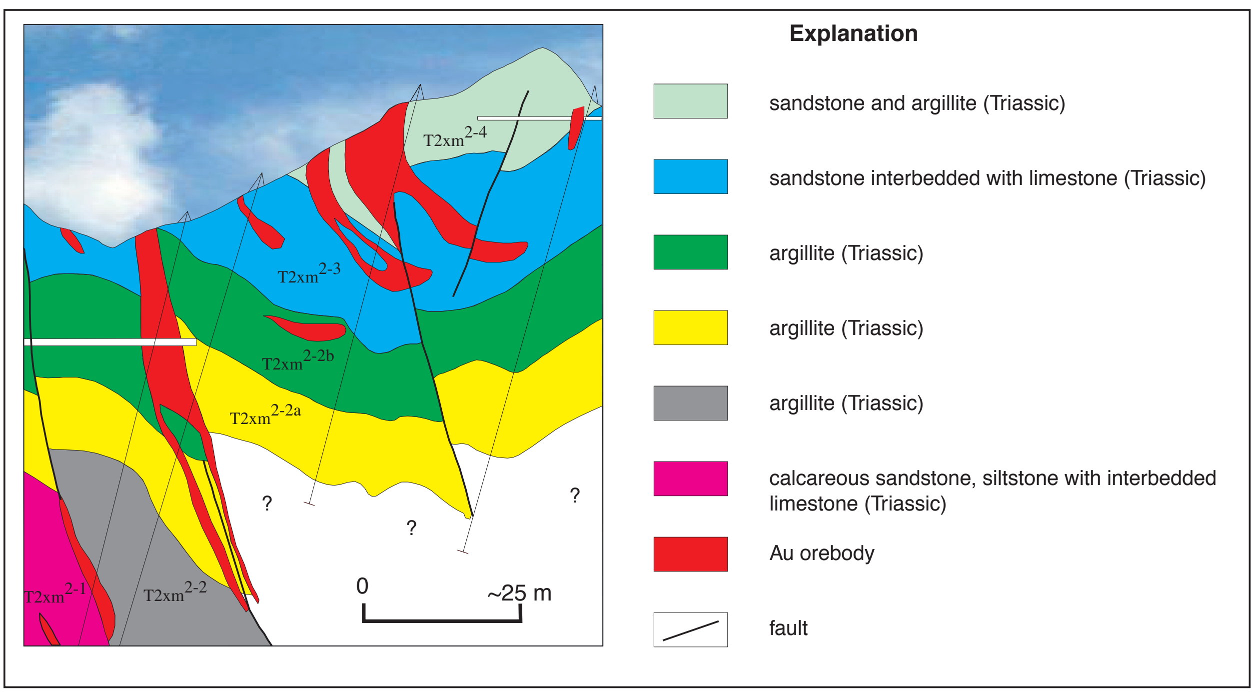

Figure 3-27. Geological section of the Yata Au deposit, Guizhou Province, Dian-Qian-Gui area showing faults and folds that control the orebodies. Adapted from Tao, C.G. (1990).

Alteration consists of silicification, carbonatization, and introduction of arsenopyrite, kaolinite, and ferrodolomite. Ore-bearing minerals mainly are pyrite, stibnite, arsenopyrite, marcasite, chalcopyrite, and realgar. Gangue minerals consist of quartz, ferrodolomite, and clay minerals. Gold mainly is contained in pyrite (62.13 weight percent), then clay minerals (35.01 weight percent).

Getang Au deposit

The Getang Au deposit is in Anlong County, Guizhou Province 27 km in a northwest 315° direction from the Anlong County town at 105° 09' 30" E, 25° 11' 40" N. The Getang Au deposit consists of more then 10 orebodies that are northeast-striking, southeast 10ʃ-dipping, stratabound, near-horizontal layers, bands, and irregular forms. The main orebodies are 400 to 1,000 m long, 400 to 700 m wide, 2.47 to 4.27 m thick and grade 4.70 to 6.01 g/t Au. The small ore pods are 100 to 300 m long, 2.1 to 3.5 m thick and grade 3.5 to 5.10 g/t Au. The reserve of the Au deposit is more than 22.48 tonne Au (by the end of 1996). The deposit was not visited as part of this study and information is compiled from Tao, C.G. (1990) and Cheng, J.H. (1994).

Rocks exposed in the Getang Au Mining District are sedimentary rocks of the Permian and Triassic Series. The Getang Au deposit is hosted in siliceous, brecciated argillite, and siliceous limestone breccia. These breccia bodies are present at the unconformity surface between the Longtan (P_2l) and Maokou (P_1m) Formations (Tao, C.G., 1990; Cheng, J.H., 1994). The Getang Au deposit mainly is hosted in the bottom horizons of the Upper Permian Longtan Formation (P_{2l}^1). The upper and lower horizons of this unit are argillite and breccia and not favorable hosts for Au, but the middle 1– to 10–m-thick (maximum, 40–m-thick) silicified limestone and argillite breccia horizon is also a Au host (fig. 3-28).

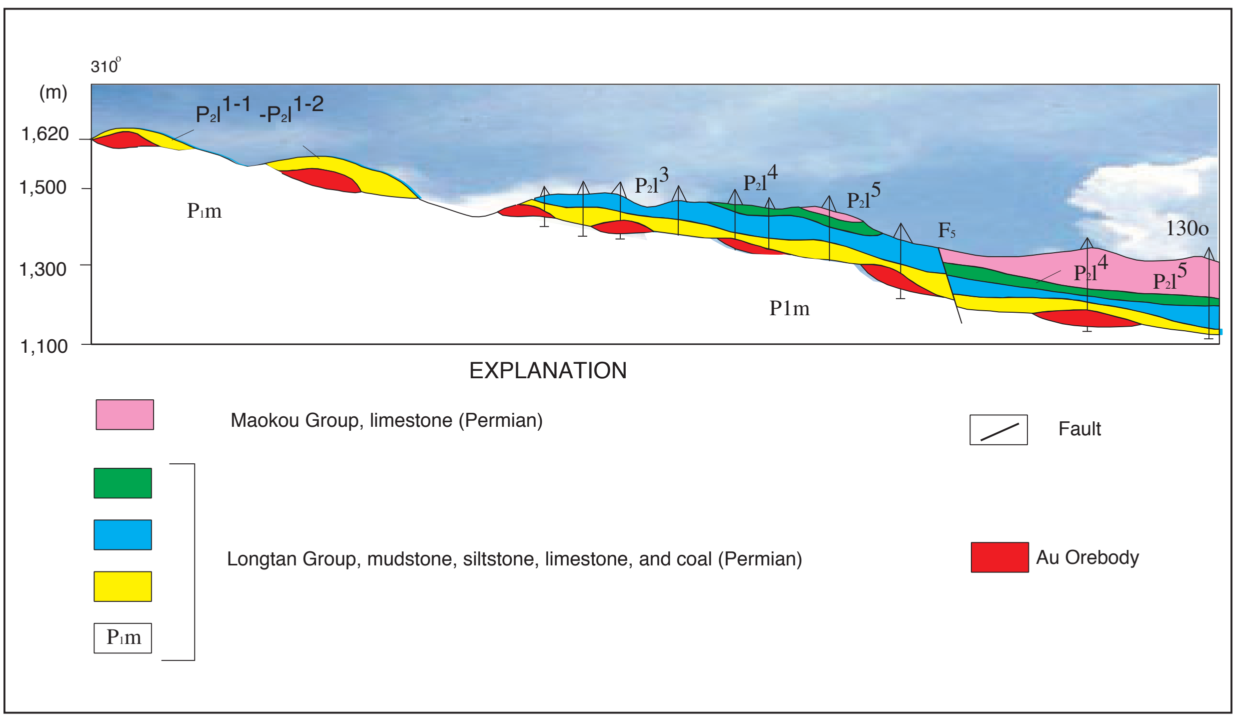

Figure 3-28. Geological section of Getang Au deposit, Guizhou Province, Dian-Qian-Gui area. Orebodies are located on the unconformity between units P2l3 and P1m and have the shape of the low-lying land surface, which was formed on the old erosion surface. Adapted from Tao, C.G. (1990). For latitude and longitude, see Appendix IV.

The Getang Au deposit lies along the southeast limb of the Getang anticline. The anastamosing, northeast-striking, several km-long Haimagu and Shanghe-Lugou faults (not shown on figure 3-28) intersect the unconformity surface of early Permian rocks and developed tensional and sheared zones along a trough-shaped valley and depression that consists of mineralized paleo-karst and Au-bearing breccia, which hosts the Au orebodies (fig. 3-28).

Ore minerals in the Getang Au deposit are native Au, pyrite, pyrrhotite, chalcopyrite, arsenopyrite, stibnite, realgar, orpiment, cinnabar, galena, sphalerite, molybdenite, and magnetite. Native copper and native zinc also have been reported. Goethite and jarosite are prevalent ore minerals in the oxide zone. Gangue minerals are quartz, calcite, kaolinite, hydromica, muscovite, biotite, epidote, hornblende, garnet, barite, apatite, zircon and rutile. The oxide ores have pseudomorphic and colloform textures and much of the ore is fine-grained. The ores are present in breccia, veins, and disseminations. Alteration at the Getang Au deposit mainly is silicification with the introduction of kaolin, dickite, fluorite, minor chlorite calcite, and gypsum.

The Getang Au deposit has many similarities to the Gedang Au deposit in Yunnan Province, and the Changkeng Au deposit in Guangdong Province (Du, J.N. and Ma, C.K., 1994; Li, Z.P., and Peters, 1998), specifically because these deposits are controlled by an unconformity or paleo-erosional surface that has been over printed by faulting and shearing. Mineralogy of the Getang Au deposit is similar to many of the other sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area, although the presence of molybdenite, biotite, epidote, and hornblende indicate a likely igneous component that generally is lacking in the other deposits.

Sixianchang Au–Hg deposit

The Sixiangchang Au–Hg deposit in the southwest part of Guizhou Province, Puan County is approximately 8 km northwest of the Puan County town at 25° 55’ N, 105° 00’ E and lies in the northwest part of the Dian-Qian-Gui area (fig. 3-1) (Li Z.P., and Peters, 1998). The deposit was not visited as part of this study and information is compiled from sources noted below. The area is the site of a newly discovered (1998) Carlin-type Au deposit composed of 13 Au orebodies (not all shown on fig. 3-29) with average grades of 7.19 g/t Au. The Sixiangchang Au–Hg deposit was discovered in a large, old Hg deposit that has been developed by mining to a depth of 500 m (Huang, G.S. and Du, Y.Y., 1993). The deposit is part of the large Shuiyichange Hg orefield (He, L.X., and Zheng, R.L., 1992). Gold and Hg orebodies are 25 to 300 m long and are present as separate or locally zoned bodies along strands of northeast-striking faults and mostly are hosted in thick-bedded late Cambrian limestone, micritic limestone, sandstone, and argillaceous siltstone and limestone (fig. 3-29).

The Sixianchang Au deposit is located in the north-south-trending Sandu-Danzhai Au belt (Huang, G.S., and Du, Y.Y, 1993). Ore is controlled by high-angle faults along the north-northeast-trending west limb of the Zhushachang-Duimenzhai syncline.

Ore minerals consist of native Au, electrum, arsenopyrite, pyrite, marcasite, cinnabar, native Hg, stibnite, and sphalerite. Gangue minerals consist of sericite, carbon, clay, quartz, calcite, ankerite, dolomite, barite, and gypsum.

The Sixiangchang and Shuiyichange areas have similarities to Au–(As)–Hg–(Sb) mineralized zones in Gansu and Sichuan Provinces in the Qinling fold belt area that are hosted in Permian and Triassic carbonate and clastic rocks, such as Manaoke, Shijiba, and Zhongqu Au–Hg deposits (Li, Y.D. and Li, Y.T., 1994). The Sixiangchang Au–Hg deposit has many similarities to other sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area, however it differs because of the older host rocks, and the abundance of Hg deposits.

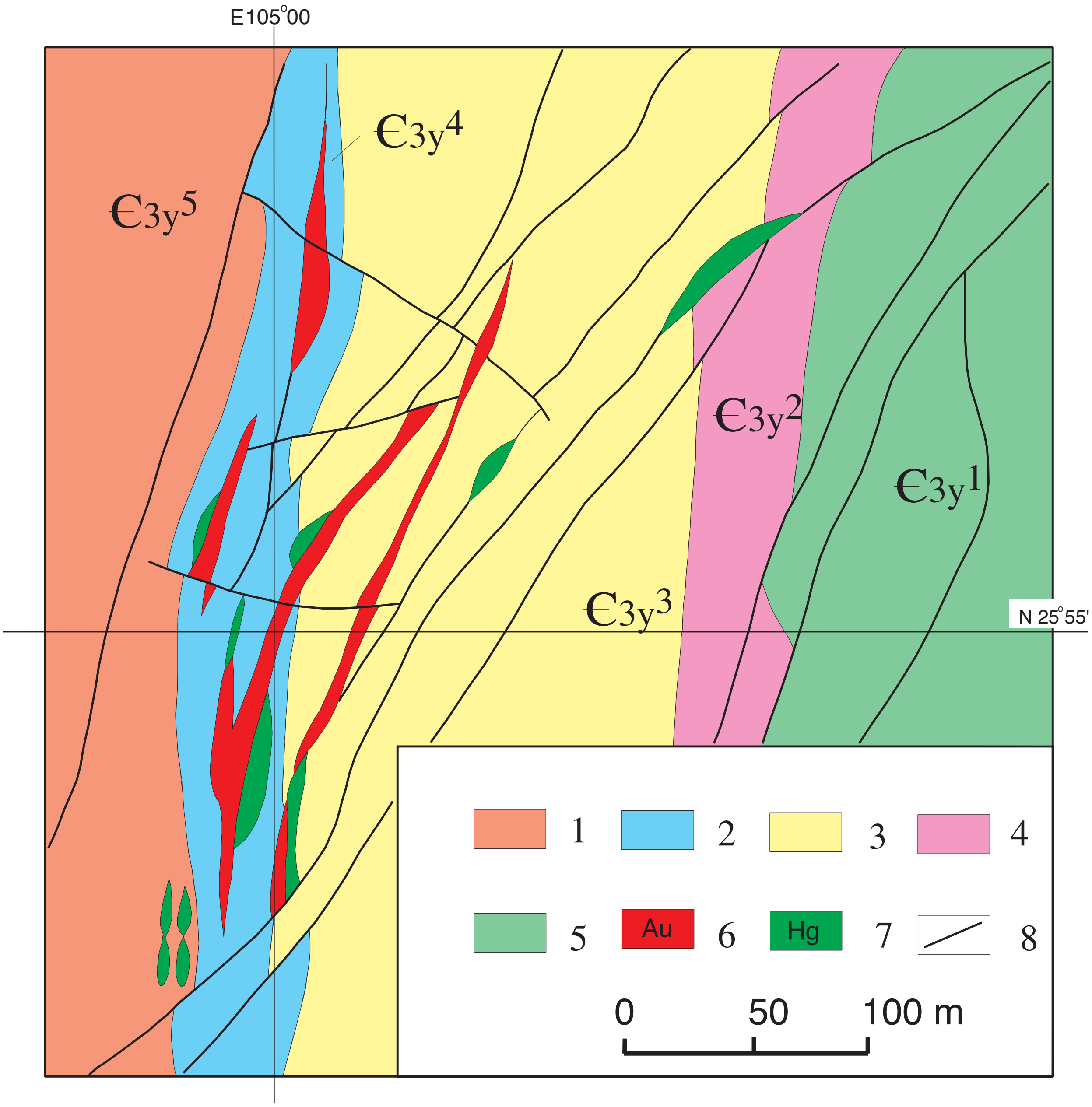

Figure 3-29. Geological plan of 405 m level of the Sixiangchang Hg-Au deposit, Guizhou Province, Dian-Qian-Gui area. Gold and Hg orebodies are controlled by the same faults in this deposit. 1-micritic limestone, argillaceous siltstone; 2-thick limestone; 3- micritic limestone, argillaceous siltstone; 4-thick limestone, strip micritic limestone and argillaceous siltstone; 5- micritic limestone, argillaceous siltstone; 6-Au orebody; 7-Hg orebody; 8-fault. Adapted from Huang, G.S. (1993). Latitude and longitude approximate.

Jinya Au deposit

Jinya Au deposit is situated in Fengshan County, Guangxi District near the Guizhou-Guangxi boarder about 18 km in a 278° direction from the Fengshan County town at 106° 52'30" E, 24° 34'05" N. The deposit was not visited as part of this study and information is compiled from Wang, K.R. and Zhou Y.Q. (1992) and Li, Z.H. and others (1994). The deposit is hosted in Triassic rocks and is controlled by bedding-plane faults (fig. 3-30). The Jinya Au deposit consists of 20 orebodies that are present as east-dipping, locally west-dipping, conformable or semi-conformable layers and lenses. The main Jinya Au zone is 3.5 km long, 300 to 700 m wide, and strikes north. The zone is composed of three blocks that lie along a main shear zone. A single lens or orebody usually is 100 to 350 m long, 1 to 5 m thick, and 50 to 400 m deep, grading 5.2 g/t Au.

Rocks exposed in the Jinya Au Mining District are Devonian, Carboniferous, Permian, and Triassic. Middle Triassic turbiditic argillic sandstone with well-defined Bouma sequences of the Baifong Formation (T_2b) is spatially related to the Au orebodies and is divided into three members: The upper member is composed of dolomitic-argillaceous siltstone intercalated with dolomitic mudstone. The 213– to 783–m-thick middle member is the main Au ore host horizon and is composed of a top 33.7–m-thick interval of silty mudstone intercalated with argillaceous siltstone a lower interval of argillaceous siltstone. The lower member is composed of argillic siltstone, silty mudstone, and fine-grained sandstone (fig. 3-30).

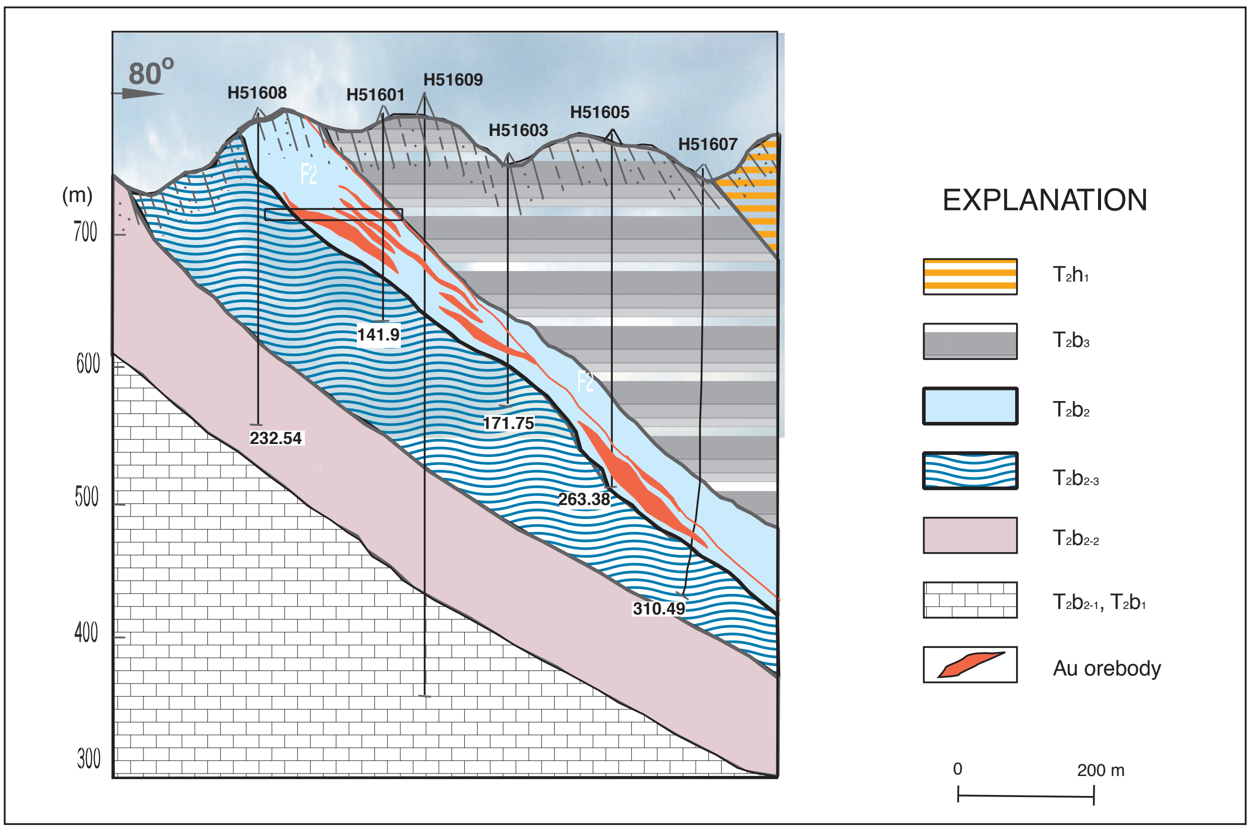

Figure 3-30. Geologic section from the Jinya Au deposit, Guangxi District, Dian-Qian-Gui area, showing ore-control along lithofacies contact between Triassic sedimentary rock units T2b2 and T2b3. Adapted from Li, Z.H. and others (1994). For longitude and latitude, see Appendix IV.

Faults are common in the Jinya Au deposit area. A compressive north-striking 13–km-long, 300– to 500–m-wide (F_1) shear zone parallels the basement contact. Subsidiary normal and reverse faults are widespread in this compressive zone. Two groups of normal faults also are present. One group has a northeast dip direction toward 55 to 90° at 30 to 80° and the other has a northwest dip direction of 250 to 280°, at 35 to 65°. Reverse faults post-date most other structural movement in the compression shear zone and mainly dip east, but some dip to the west. Gold mineralized rock is strictly contained in and controlled by the compression shear zone (Li, Z.H. and others, 1994).

Hydrothermal alteration in the Jinya Au deposit mainly is silicification accompanied by the introduction of sulfide and carbonate, and micaceous clay minerals. Primary ore is divided into three types: (1) pyrite ore, (2) pyrite-arsenopyrite ore, and (3) arsenopyrite ore. Ore minerals are pyrite, arsenopyrite, sphalerite, galena, chalcopyrite, siderite, realgar, orpiment, stibnite, marcasite, native Au, and native arsenic. Limonite is common in the oxide ores. Gangue minerals are quartz, calcite, dolomite, chlorite, kaolinite, sericite and hydromica. Ore minerals have a variety of textures, including girdle, replacement, dissolution, crushed, colloform, bioclast, and radiating. Orebodies contain mesoscopic structural textures also, such as disseminated, concretion, stockwork, veinlet, massive, brecciated, and banded (Wang, K.R. and Zhou Y.Q., 1992; Li, Z.H., and others, 1994). Arsenopyrite, pyrite, quartz, and carbonate minerals are the main carriers of Au. Gold is present as micron-sized inclusions in arsenopyrite and pyrite and as colloform adsorption on clay minerals. Gold minerals mainly are native Au and rare electrum present as very fine-grained, <0.2–to 1–μm-sized grains.

Gaolong Au deposit

The Gaolong Au deposit, also known as the Jigongyan orebody of the Gaolong area, is about 60 km northwest of the city of Tianlin in hilly country above the town of Beise at 105° 42' 00" E, 24° 13' 12" N, in north Guangxi District (fig. 3-1). The mine was visited in 1997 by the authors and the following information results from data gathered during this visit and laboratory studies and from the Nanning Geological Survey of the Ministry of Metallurgical Industry. The mine lies among several limestone mines and other sedimentary rock-hosted Au prospects and smaller mines. The Jigongyan ore block is located in the eastern part of the orefield. Orebodies also have been found in the Jinlongshan and Youai blocks. Geologic work on the deposit started in 1985 and orebodies in the Jigongyan area were discovered at the end of 1986, and 11.5 tonnes Au reserve were proven by 1990. The Gaolong mine started construction in 1991 and production at the end of 1993 was 10 thousand oz Au per year.

The mineralized zone in the Gaolong deposit is 1,700 m long, 47.8 m wide, and 288 m deep. A total of 9 orebodies have been defined in the Jigongyan ore block. Of these the No. 6 orebody is the biggest and contains about 96 percent of the total reserve. This deposit is 800 m long, 23.69 m wide and 285 m deep, with an average tenor of 3.55 g/t Au at the surface. The Gaolong Au deposit orebodies are layer-like and lenticular, dipping north or northeast at 50 to 60°. Orebodies are 90 to 850 m long, 3.33 to 17.60 m thick, and extend 80 to 200 m deep. Gold grade is 1.79 to 4.04 g/t Au. The orebodies generally pinch, swell or branch. All orebodies are present along a silicified structural breccia zone (F_3) or its secondary faults.

Ore mined to 1997 was dominantly oxide ore along a moderately north-dipping, 50–m-wide linear zone along the crest of a hill (fig. 3-31). Mining is by under cut methods at bench faces with hand tramming by two-wheeled burrows to crushers and hoppers and is then sent by truck to heap leach piles (figs. 3-31, 3-32). Blasting and back-hoe excavation also supplement these methods. The mining area is about 1 km long, along strike, and contains a central, main 100– to 150–m-long oreshoots (Dragon's body) and several smaller orebodies to the northeast and to the southwest (figs. 3-31, 3-32, 3-33).

District geology around the Gaolong Au deposit consists of middle Triassic Baifeng Formation (T_1b_2) sandstone and mudstone to the northeast of the deposit that surrounds the Gaolong dome (fig. 3-33).

Strata exposed in the Gaolong Au Mining District are the Middle to Upper Carboniferous (C_{2+3}), Lower Permian (P_1), Upper Permian (P_2), Lower Triassic (T_1), and Middle Triassic Baifeng (T_2b) and Hekou (T_2h) Formations. The 650– to725–m-thick Baifeng Formation (T_2b) is the main host to Au mineralization and is composed of three members. The Lower member (T_2b^1) contains calcareous mudstone intercalated with calcareous siltstone with minor siliciclastic rocks. The Middle member (T_2b^2) is composed of siltstone intercalated with mudstone. The Upper member (T_2b^3) is composed of fine-grained sandstone intercalated with siltstone. Gold ore mainly is hosted in the upper member.

The deposit is located on both limbs of the 7–km-long, 6–km-wide, west-northwest-trending Gaolong dome and the Au zones are controlled by arcuate faults around this dome. The orebody is present along the northwest-striking contact between middle Triassic (T_1b_2) rocks and Permian limestone (P_2c), which makes up the core of the Gaolong dome. The contact between these two stratigraphic units is a silicified deformation zone that is characterized by siliceous breccia, ductile phyllonite, gouge zones, and local intense folding (figs. 3-34 and 3-35).

Figure 3-31. Photograph of panoramic view of Gaolong Au deposit, Guangxi District, Dian-Qian-Gui area, looking northeast. Main open pit mining area is on the left central part of photograph. Jagged spires in the skyline indicate silica caps and siliceous parts of the orebody. Waste dump is located below open pit. In the foreground, in the right side of the photograph, are cyanide heap-leach piles.

Figure 3-32. Photographs of mining methods at the Gaolong Au mine, Guangxi District, Dian-Qian-Gui area. (*A*) Mining by under-cut methods of oxide ore by hand at the base of a bench. (*B*) View of top of hopper (behind workers) where ore is hand-trammed approximately 50 m from the bench face.

Exploration around the dome, and in areas to the northeast of the dome, has generated several prospects and deposits and As–Au geochemical anomalies. The core of the anticline is composed of units C_{2+3}, P_1, and P_2 and the limbs are composed of units T_2b and T_2h. Two groups of faults are present near the dome that strikes both east-west and north-south.

A central deformation zone is host for ore and strikes about 120° northwest-southeast and is about 100 m thick (fig. 3-34). The northeastern parts of the zone are in contact with siliceous Triassic rocks and contain several brittle-ductile shear planes, especially along zones of carbonaceous gouge and phyllonite (fig. 3-35*A*). Tight folding and phacoid development also is present in thin-bedded, muddy turbidite rocks along this zone (fig. 3-35*B*). The southwestern parts of the deformation zone are in contact with Permian limestone and dolomite and are variably decalcified and brecciated (fig. 3-35C). In the central part of the deformation zone, hard, undecalcified limestone, silicified zones, and turbidite blocks are surrounded by clay and sericite gouge planes that anastamose on a meter-scale around them (fig. 3-35*D*). Orebodies along the silicified, brecciated deformation zone are localized along an interformational cataclastic and fracture detachment zone near or at the intersection of two groups of faults. Silicified tectonic breccia and silicified, crushed, clay-bearing sandstone are the main host rock lithologies.

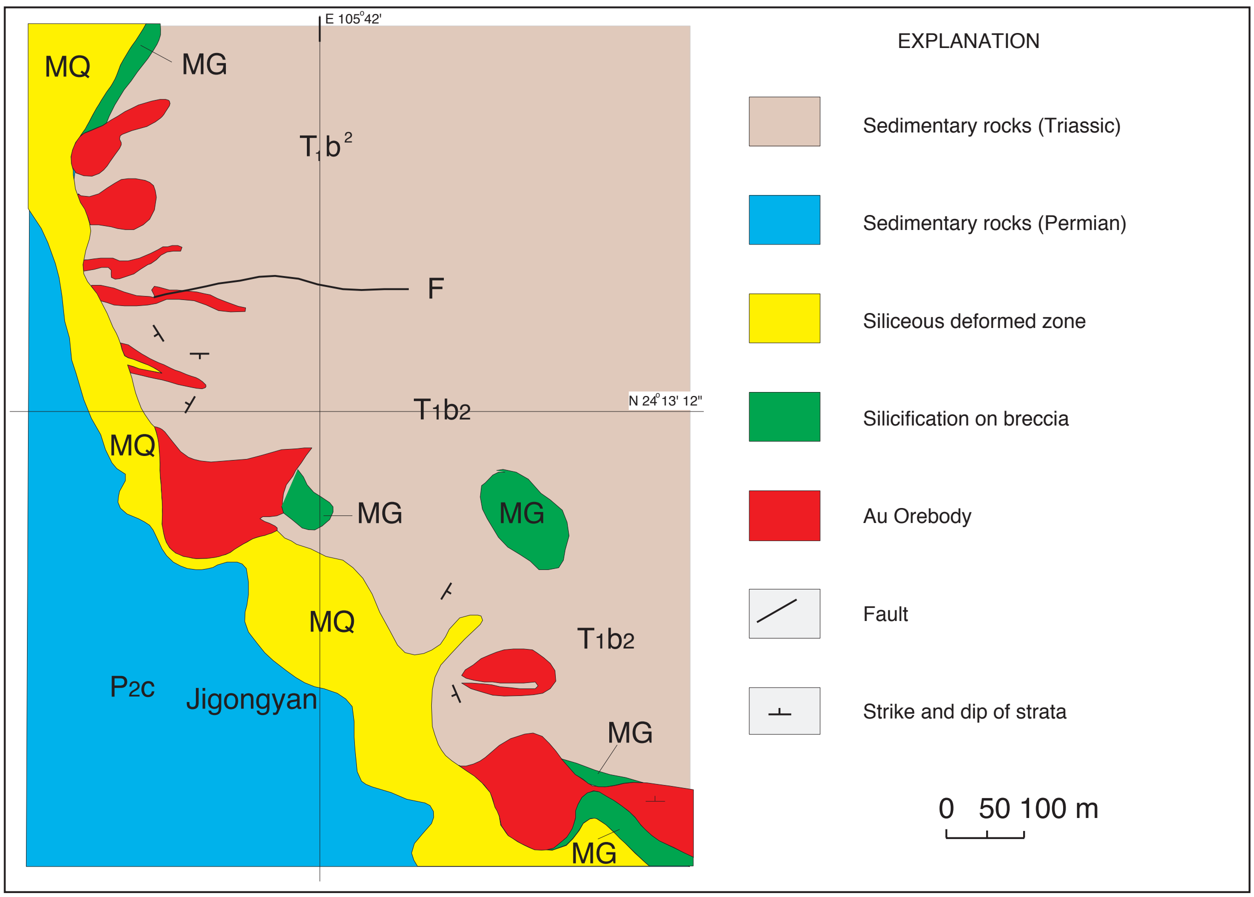

Figure 3-33. Silicification cap in Gaolong Au deposit area, Guangxi DistrIct, Dian-Qian-Gui area, showing silicified breccia rock (MG) and quartz over prints on breccia zones (MQ), that are closely associated with Au orebodies. Adapted from the Second Team of Geology, Guangxi District (Liu, D.S. and others, 1994). Longitude and latitude are approximate.

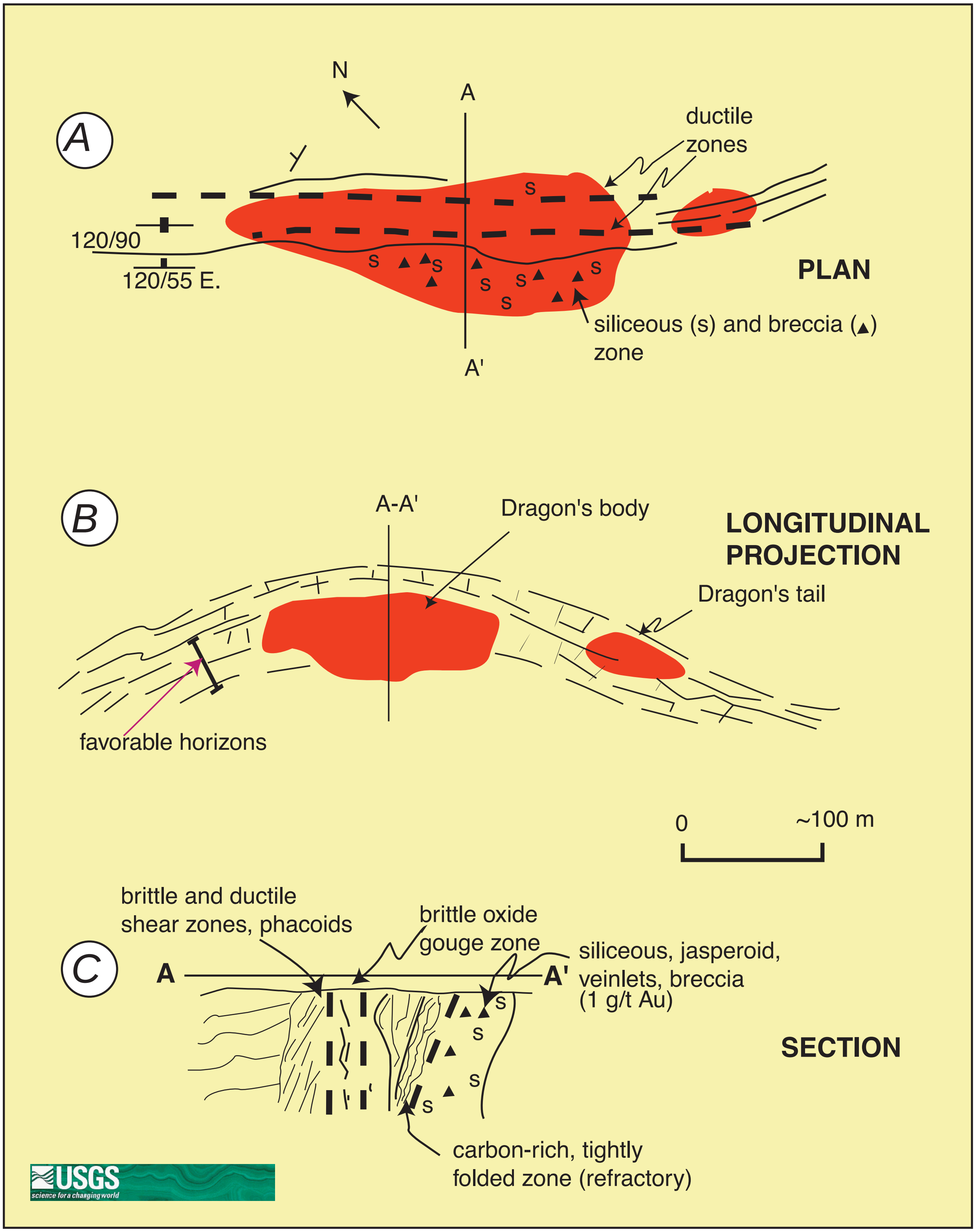

Figure 3-34. Diagrammatic sketches of the Gaolong Au deposit, Guangxi District, Dian-Qian-Qui area. (*A*) Plan sketch showing ductile shear zones and brittle shear zones. (*B*) Longitudinal projection diagram showing favorable ore horizons. (*C*) Diagrammatic section showing elements of brittle and ductile shearing and faulting across the orebody. Scale approximate.

Alteration mainly consists of jasperoidal silica (fig. 3-36) and sericite with local addition of carbon. Alteration is present along intensely altered or brecciated parts of the deformation zone. Siliceous breccia is commonly a network, rather than clast, breccia containing 0.25– to 1.5–cm-thick irregular-shaped, clear to milky quartz veinlets (fig. 3-37*A*). The veinlets cross cut the matrix and local fragments. Silicification is very fine grained (fig. 3-37*B*, 3-37*C*) and contains (<0.02– to 0.2–mm-diameter) quartz and local coarser (0.4–mm-diameter) quartz as clumps or in local micro-vugs. Hypogene ore minerals, or those preserved in siliceous zones, are pyrite and As-rich pyrite. These sulfide minerals are most prevalent as <0.1–mm-diameter disseminations in rock along the structural zones. Illite and quartz are the main gangue minerals.

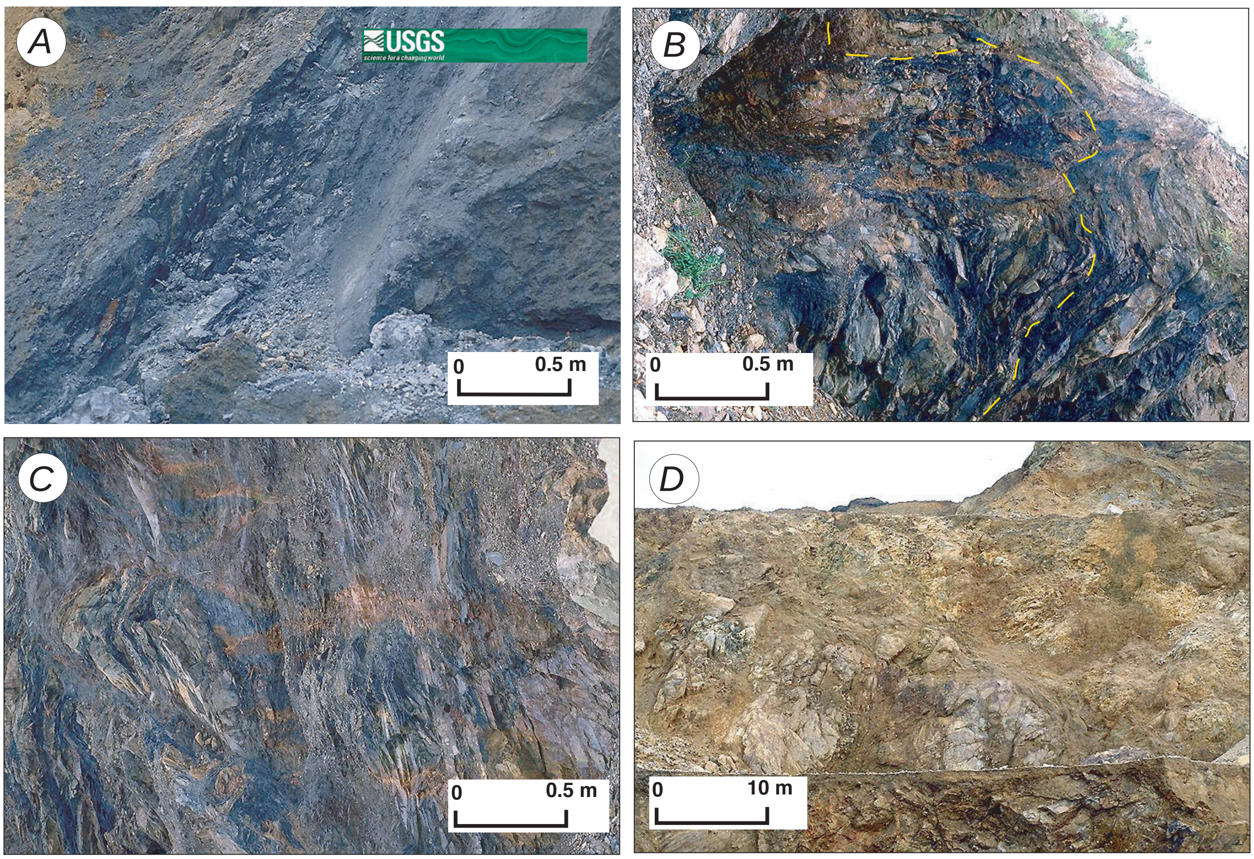

Figure 3-35. Photographs of examples of structural textures associated with the Gaolong Au orebody, Guangxi District, Dian-Qian-Gui area. (*A*) Carbonaceous ductile zone with refractory ore along central part of orebody. (*B*) Highly folded and intensely deformed and phacoidal, thin-bedded strata on northwest side of orebody. (*C*) Mine bench face of siliceous breccia on west side of orebody. (*D*) Oxidized mine face looking parallel to the strike of the orebody. Note large, rounded blocks disturbed by shearing and intense faulting along the ore zone.

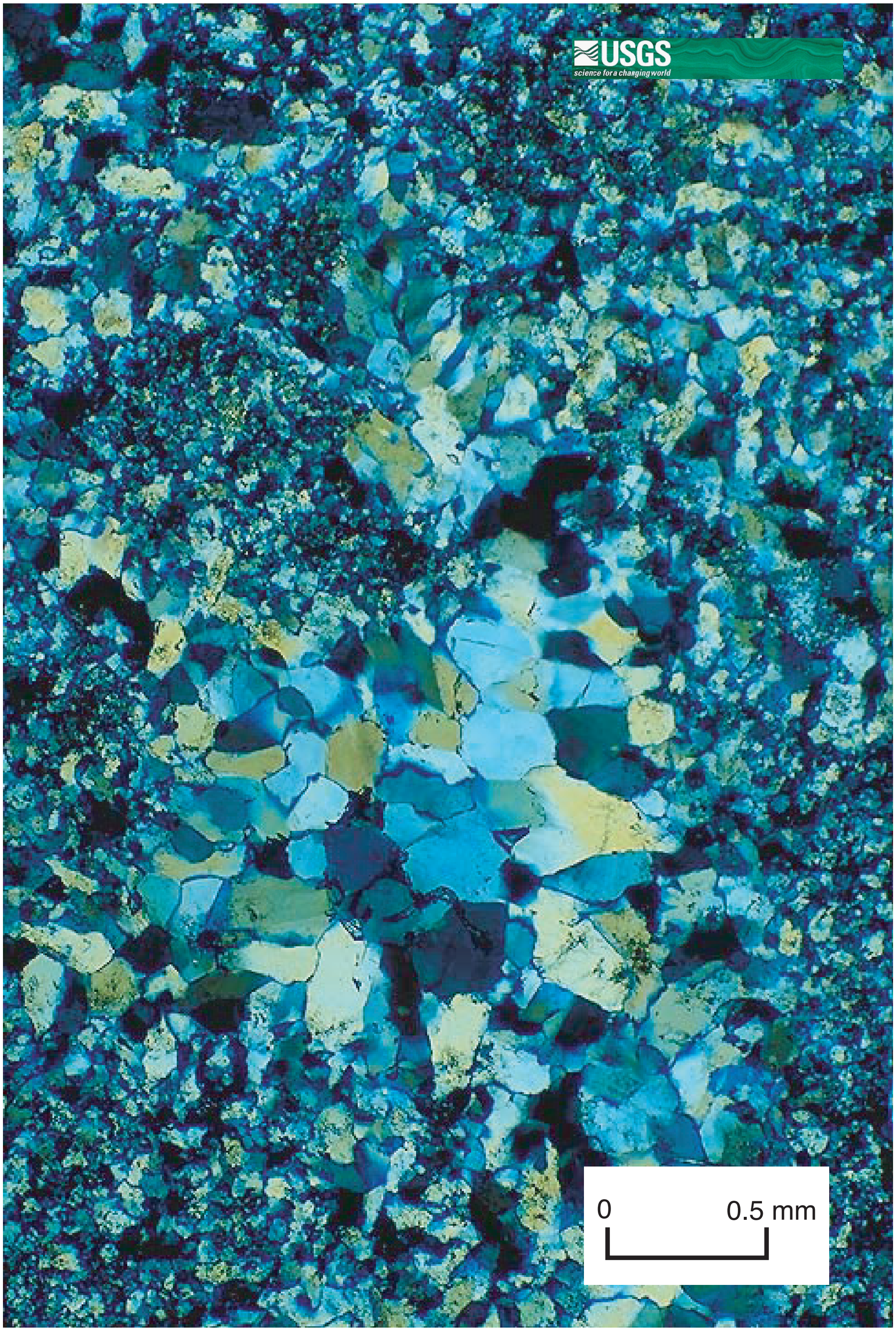

Figure 3-36. Micro phototograph of siliceous breccia (jasperoid) at the Gaolong Au mine, Guangxi District, Dian-Qian-Gui area. Dustier areas ares are clay and sericite particles. Coarser quartz may be vug in-filling or texturally destructive replacement.

The Gaolong Au deposit ores are divided into two types: (1) primary ore, and (2) oxidized ore. The oxidized ore is dominated by limonite as the main ore mineral, but also contains pyrite, arsenopyrite, minor galena, sphalerite, and chalcopyrite. Oxide ore is typified by granular, colloform, and replacement-inclusion textures that have porous, earthy and clastic brecciated sub textures. Primary ore has three subtypes:

(1) tectonized quartzose ore, composed of hydrothermal quartz, with granoblastic textures and a massive structure. The Au grade is lower, generally less than 1 g/t Au, but locally up to 2 to 3 g/t Au.

(2) silicified breccia ore composed of fragments of siltstone and mudstone cemented by hydrothermal quartz. It is the main type of ore; and

(3) silicified, crushed, clay-bearing sandstone ore with blastopsammitic and blastoargillic textures. Quartz veinlets and stockworks are widely spread in the ore.

Native Au mainly is present in the oxide ores as intergranular Au (71.09 weight percent), then inclusion Au (18.25 weight percent), and as fracture Au (10.66 weight percent). The size of native Au grains generally is between 0.01 and 0.005 mm, but also is between 0.037 and 0.010 mm (fig. 3-37*D*). Hypogene Au may be associated with arsenical pyrite. Geochemically, the oxide and pyritic siliceous ores in the current (1997) mine exposures are anomalous in Ba and

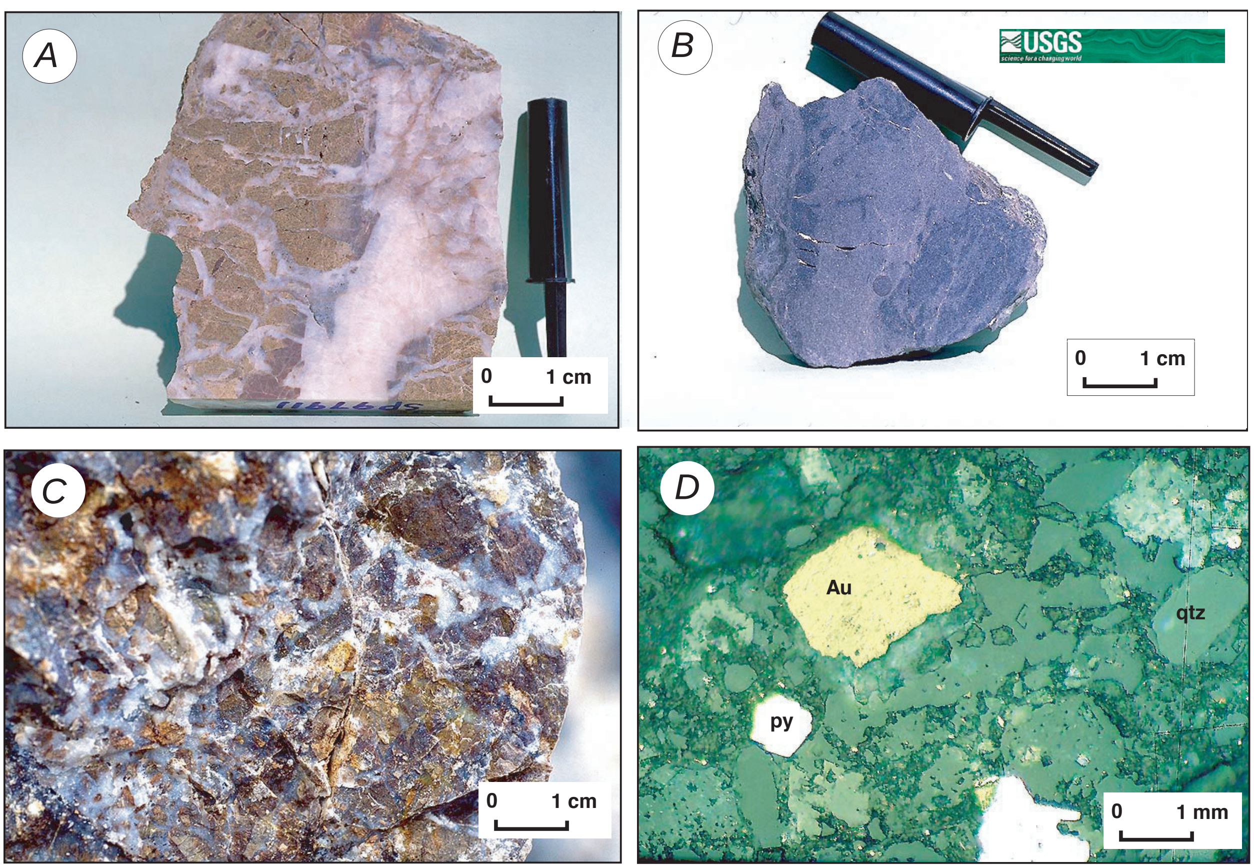

Figure 3-37. Photographs of oxide ore types in the Gaolong Au deposit, Guangxi District, Dian-Qian-Gui area. (*A*) Milky quartz veinlets in oxidized sandy limestone. (*B*) Mottled, slightly oxidized sandy limestone in central zone. (*C*) Jasperoidal breccia in south margin zone. (*D*) Micro photograph of polished thin section showing disseminated Au, pyrite, and quartz in siliceous ores.

Mn and slightly elevated in As (<1,900 ppm). Most other elements, particularly Sb, Pb, Ag, and Zn have values <100 ppm (Appendix IV). These are typical geochemical signatures from most Carlin-type deposits and are similar to other sedimentary rock-hosted Au deposits in the Dian-Qian-Gui and Qinling fold belt areas.

Deformation textures along the main host structural zone in the Gaolong Au deposit, such as intense folding, brecciation, phacoid development, and silicification are similar to many structurally-controlled Carlin-type orebodies in Nevada, such as the Betze orebody (Peters, 1997, 2000a, b; Peters and others, 1998, 2000). Mineralogically and geochemically, the Gaolong Au deposit has less typical minerals or strong geochemical signature than other sedimentary rock-hosted Au deposits. This may be a result of supergene processes, but may also suggest a different type or weaker system than most Carlin-type Au deposits elsewhere in the Dian-Qian-Gui area. The structural and geologic setting of the Gaolong Au deposit is similar to other sedimentary rock-hosted Au deposits and therefore it is likely that it is part of the same metallogenic event that produced other sedimentary rock-hosted Au deposits in the region.

Gedang Au deposit

The Gedang Au deposit is in the west part of Funing County about 30 km from the Funing County town, Yunnan Province (figs. 3-1, 3-38, 3-39). The deposit is one of several sedimentary rock-hosted Au deposits in eastern Yunnan Province that lie along northwest to east-trending Au belts (figs. 3-38, 3-40) (see also, Cromie and Zaw, 2001). The deposit was briefly visited as part of this study and much of the information is compiled from The Tianjin Geological Academy unpublished reports. The production from Funing County (1997, 1998) is about 230 kg Au per year (pers. Communication, Gold Bureau, Funing County, 1999). Production mainly is from 1– to 20–m-thick, horizontal oxide zones above the sedimentary rock-hosted Au deposits and occurrences. Approximately 6 orebodies have been delineated. Their lengths are 45 to 1,025 m thick, 0.51 to 55 m wide (average 4.8 to 32.5m), with an average ore grade of 1.87 to 3.26 g\t Au. The Gedang Au belt is approximately 100 m long (fig. 3-39). Drilling has encountered a 50–m-thick orebody grading 0.5 to 3 g/t Au. With the highest grade 10 g/t Au. An Sb mine lies to the north of the main Au orebody. The mineral resource is estimated at 36 to 40 tonne Au.

Geology of the Gedang Au deposit area consists of a faulted sequence of Cambrian, Devonian, Permo-Carboniferous, and Triassic sedimentary rocks. The Gedang Au deposit is hosted in the lower member of the Devonian Pojiao Formation that consists of silty mudstone and calcareous mudstone, which is intercalated with siltstone and fine-grained siltstone and also unconformably overlies Cambrian sedimentary rocks (figs. 3-40, 3-41).

The Gedang Au deposit is controlled by shallow-dipping, interformational fracture zones along the unconformity (now a paleo-erosion) surface between the Devonian and Cambrian sedimentary formations. The Au ore zones are layer- or lens-shaped and coincide with bedding and conformable deformation planes in the host rocks. Locally, the orebodies have acute orientations to the host rock bedding planes.

Hydrothermal alteration consists of silicification and the addition of pyrite and other sulfide minerals, and local addition of calcite, and barite. Mineralogy of the Gedang Au deposit ores consists of pyrite, arsenopyrite, stibnite, As-bearing pyrite, pyrrhotite, sphalerite,

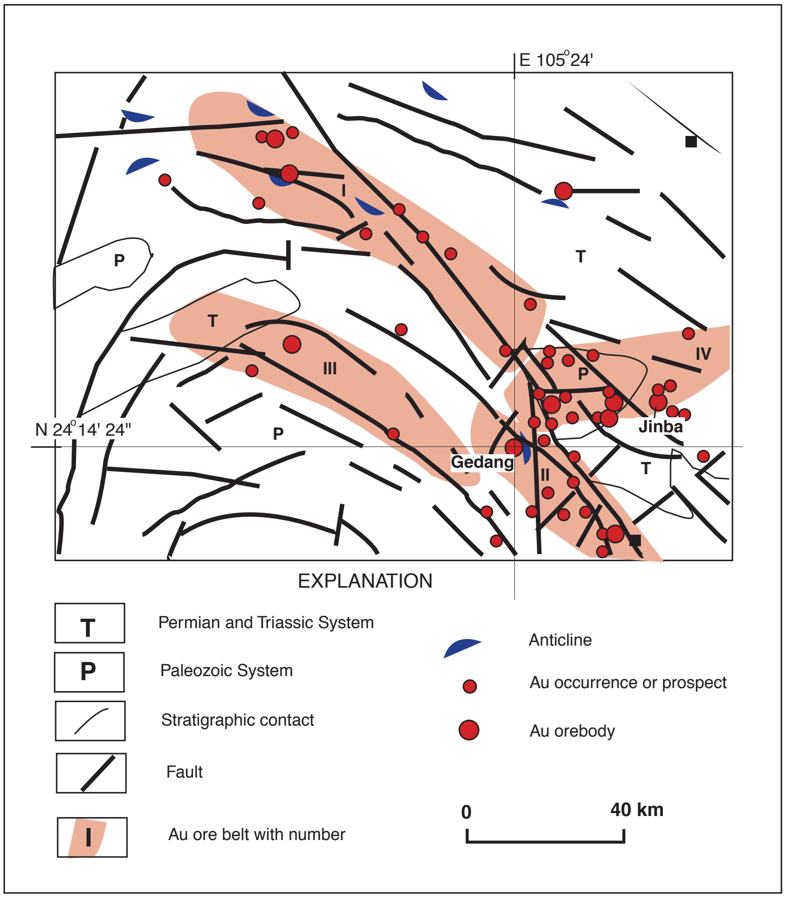

Figure 3-38. Map showing the distribution of sedimentary rock-hosted Au deposits in the Funing-Guangnan area, Yunnan Province, Dian-Qian-Gui area. The Gedang and Jinba Au deposits lie in gold belts controlled by northwest-striking district-scale faults. Latitude and longitude are approximate.

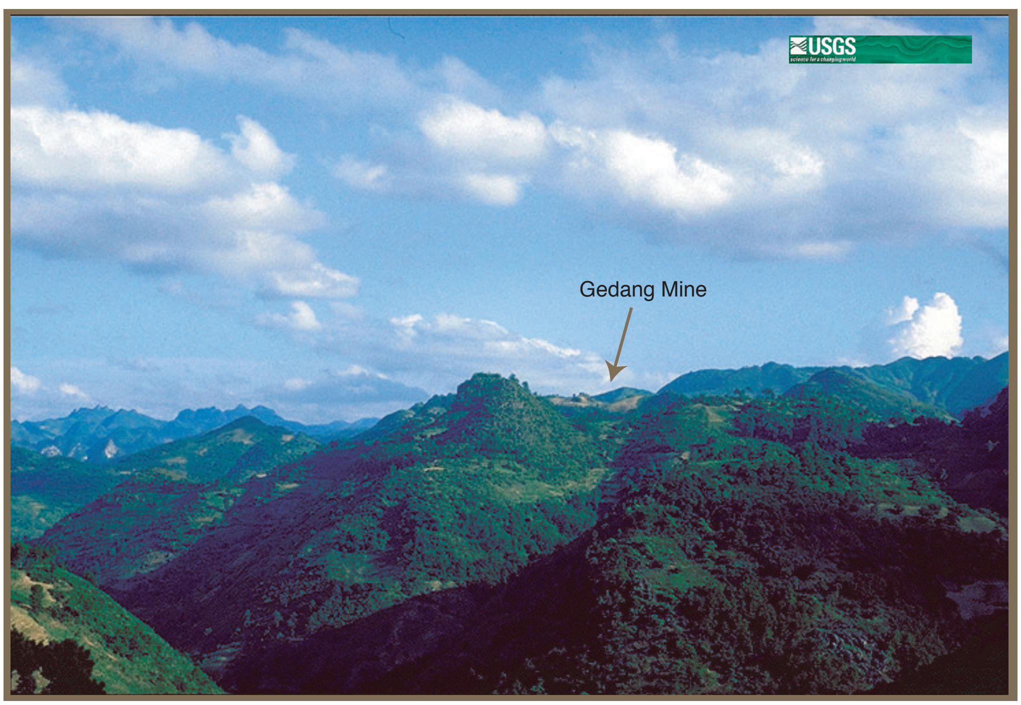

Figure 3-39. Photograph of the Gedang Au mine area, Funing County, Yunnan Province, Dian-Qian-Gui area. Looking west from main county road. Valley in forground is a northwest-striking fault system (shown on fig. 3-40).

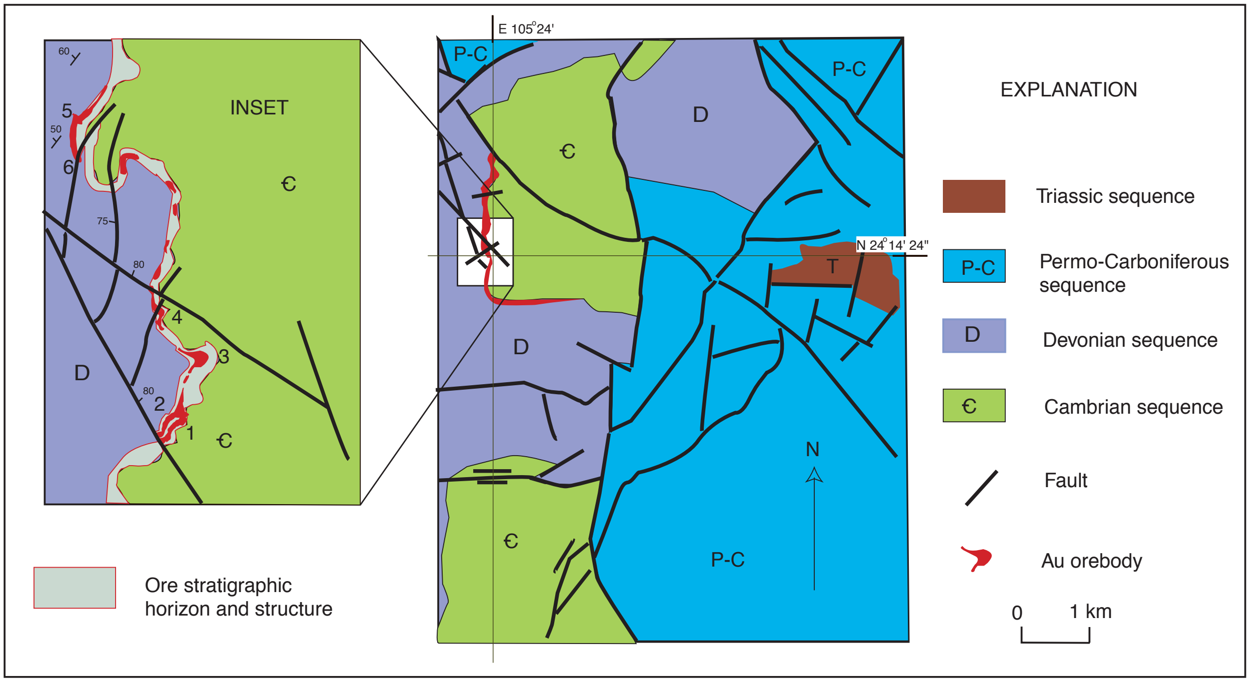

Figure 3-40. Simplified geologic map of the Gedang Au deposit, Funing County, Yunnan Province, Dian-Qian-Gui area. Ore is present along a tectonized unconformity between Devonian and Cambrian stratigraphic units. Latitude and longitude are approximate.

chalcopyrite, magnetite, and ilmenite. Hematite and limonite are common in the supergene zone. Gangue minerals consist of quartz, hydromica (sericite-illite), calcite, dolomite, barite, fluorite, and melanterite. Platinum and Pt analysis of approximately 5 samples of ore contained 0.025 to 0.208 g/t Pt+Pd (Tianjin Geological Academy, resource report).

Gold mainly is present in the Gedang Au deposit in hydromica and in sulfide minerals as micro- to submicron-sized grains. Gold is colloform-shaped in hydromica and also is present as inclusions in pyrite, arsenian pyrite, and in arsenopyrite. The occurrence and habit of these minerals is similar to other sedimentary rock-hosted Au deposits in the Funing County area and throughout most of the Dian-Qian-Gui area.

Jinba Au deposit

The Jinba Au deposit is in the northeast part of Funing County, Yunnan Province approximately 50 km from the Funing County town and is one of several sedimentary rock-hosted Au deposits and occurrences in that area. The Jinba Au deposit is part of a 3–km^{2}-size district cluster of occurrences. The deposit was visited in 1999 and information is from that visit and from the Gold Bureau of Funing County. The Jinba Au orebody is operated and registered to Ministry of Geology and Mineral Resources (2000) and regulated by the Gold Bureau of Funing County. The Au zone lies along a northeast-striking, 600–m-long, 2.5– to 4–m-wide fracture zone. Ore pods generally are 30 to 150 m long, 0.8 to 32 m thick, and are shaped like individual bands and lenses. The grade of these lenses is 4 to 5 g\t Au. Gold grades and alteration commonly grade into adjacent fresh host rocks.

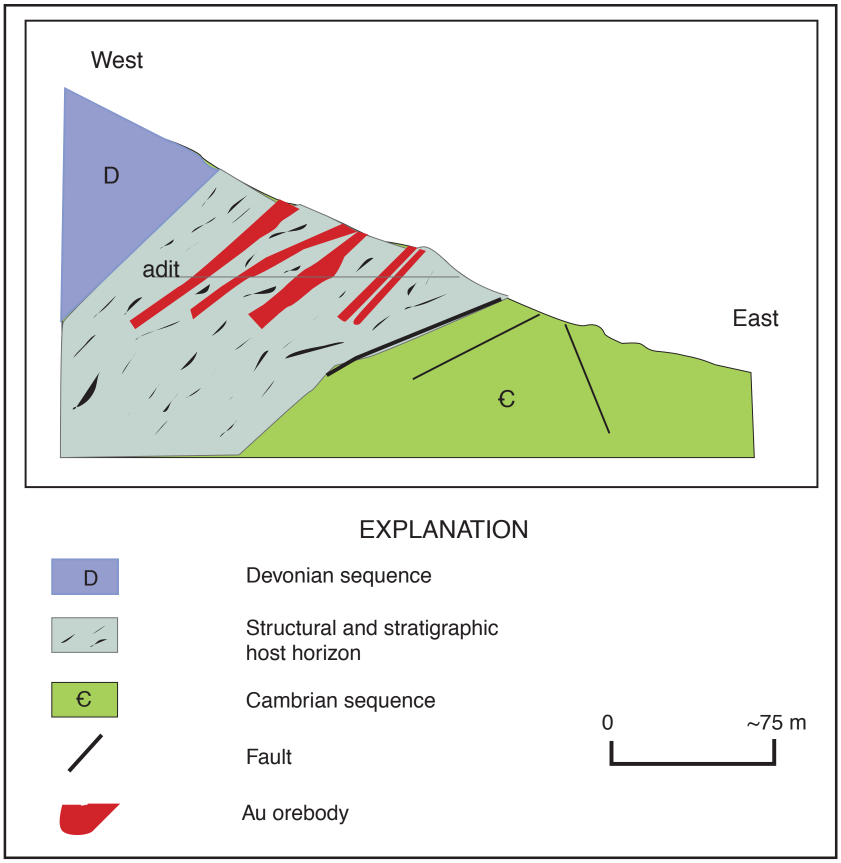

Figure 3-41. Geologic cross section through the Gedang Au deposit, Funing County, Yunnan Province, Dian-Qian-Gui area, showing ore horizon between Devonian and Cambrian rocks.

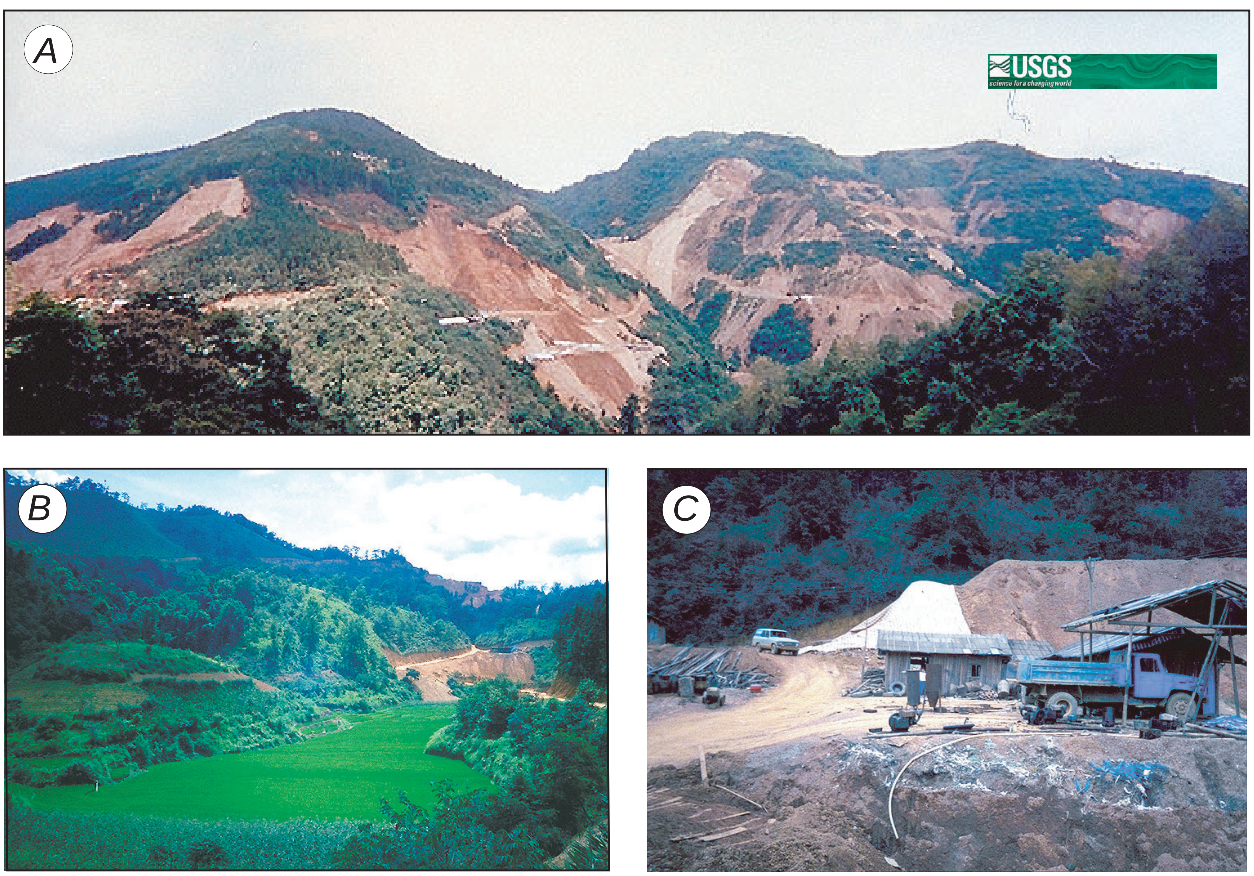

Figure 3-42. Photographs of Jinba Au deposit area, Funing County, Yunnan Province, Dian-Qian-Gui area. (*A*) Panoramic view of exploration and mining activity looking northwesterly. (*B*) Example of tropical climatic conditions near southwest part of the orebody. (*C*) Heap leach processing facility in the southwest part of the orebody. ▼

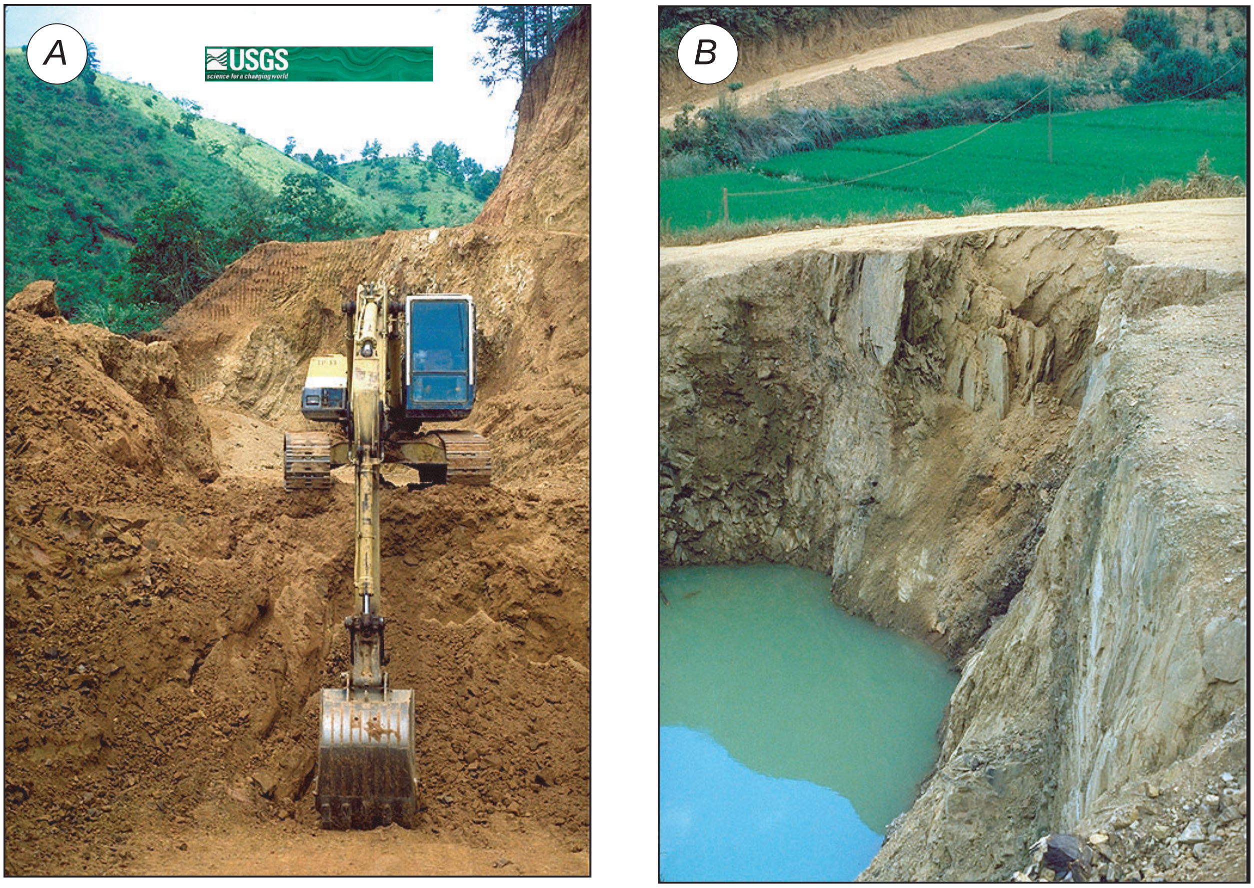

Figure 3-43. Photographs of smale-scale surface mining in the Jinba Au deposit, Funing County, Yunnan Province, Dian-Qian-Gui area. (*A*) Backhoe excavation of intensely weathered gabbroic rock; blasting is not required. (*B*) Old open pit face showing intensely weathered profile, tropical conditions, and vertical structural fabric parallel to pit wall.

The main Jinba Au deposit lies along a ridgeline of low hills (fig. 3-42). The area is tropical and weathering and weak laterite have developed a >20–m-thick, red-clay soil profile. This has allowed mining of parts of the orebody by backhoe without blasting (fig. 3-43) and processing of the ore by cyanide leach methods (fig. 3-42). The geology of the Jinba Au deposit area consists of faulted and folded Devonian and Permian limestone, sandstone, and mudstone that have been intruded by gabbroic diabase. These rocks are overlain by Triassic siltstone and mudstone, which lie mostly to the north, northwest, and southeast of the deposit and its neighboring deposits (fig. 3-44).

The Jinba Au deposit is located along the limbs of a branching anticline that contains northeast-, northwest-, and east-striking fractures and faults. Compressional northeast-striking fractures in this anticline control distribution of the orebodies, which also are often located at intersections of these and east-striking fractures where orebodies generally are thickened and enriched at the intersections. The Jinba Au orebodies lie along a northeast-striking zone and consist of approximately 21 individual ore pods above and below the Jinba horizon or structural zone (fig. 3-45). Ore is closely associated with a gabbroic diabase body along the northeast-striking ore horizon in Permian sedimentary rocks and contains elevated Au values that closely follow the contact of the mafic igneous rock (fig. 3-46).

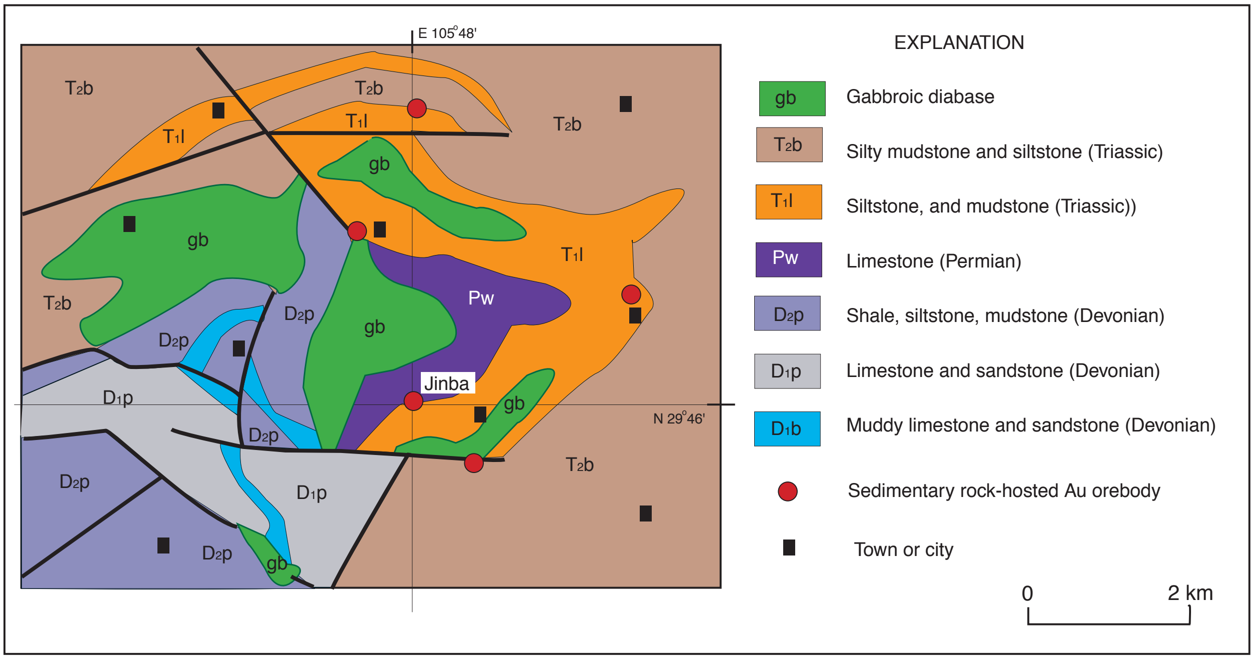

Figure 3-44. Geological map of the Jinba Au deposit area, Funing County, Yunnan Province, Dian-Qian-Gui area. Longitude and latitude are approximate.

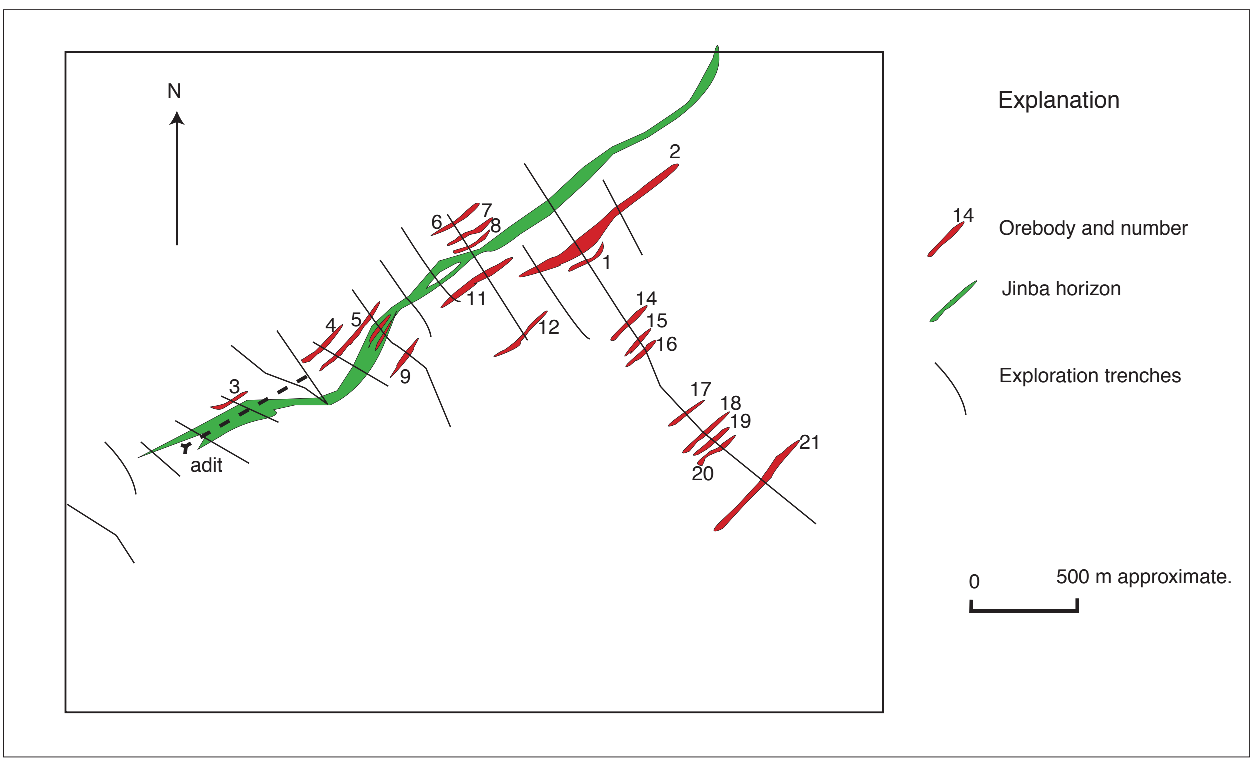

Figure 3-45. Geologic and exploration sketch map of the Jinba Au deposit, Yunnan Province, Dian-Qian-Gui area. (scale is approximate).

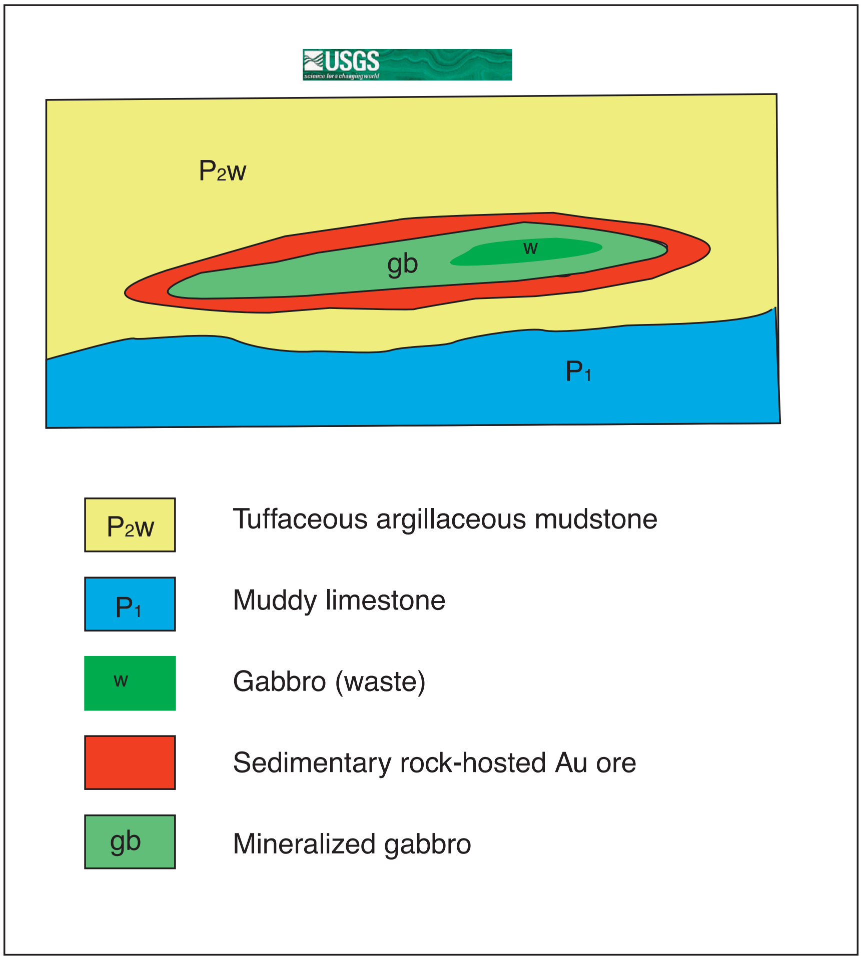

Figure 3-46. Conceptual sketch of the Jinba Au deposit, Funing County, Yunnan Province, Dian-Qian-Gui area. Gabbro and diabase sills or flows, near contact with mudstone and limestone units, is mineralized adjacent to the contact. This geometry has led some workers to associate the Au genetically to the gabbro, whereas other workers suggest that the igneous bodies only provided a good host rock. No scale.

Ore at the Jinba Au deposit is hosted by Permian limestone, muddy limestone, and argillaceous mudstone in which local siliceous rock is interbedded with mudstone, tuffaceous rock, and siltstone. Gold zones are closely related to argillaceous siltstone, tuffaceous rock, and the gabbroic diabase sills.

Hydrothermal alteration closely associated with Au consists of silicification, kaolin, and sericitic alteration. Oxide ore is dominated by limonite. Ore-bearing hypogene minerals are pyrite and arsenopyrite. Gangue minerals are quartz, sericite, calcite, and montmorillonite. Native Au is the main Au mineral.

The association of the Jinba Au deposit with gabbroic diabase suggests that the deposit may have a genetic relation to the igneous rock and therefore may have a different genesis to other deposits in Funning County, Yunnan Province, and the Dian-Qian-Gui area. Mafic rocks are known to host Carlin-type sedimentary rock-hosted Au deposits in Nevada at the Twin Creeks Au deposit (Bloomstein and others, 1991; Thoreson and others, 2000), where basalt is the host, and at the Betze deposit where lamprophyre and diorite host some ore (Leonardson and Rahn, 1996; Peters and others, 1998, 2000). Other features, such as arsenopyrite and the general location of the Jinba Au deposit in a larger metallogenic framework of sedimentary rock-hosted Au deposits in the Au belts of Funing County, and the larger Dian-Qian-Gui area, suggest that the Jinba Au deposit may also be part of the Carlin-type deposits rather than genetically associated with diabase.

Hengxian (Nanxiang) Au deposit

The Hengxian (Nanxiang) Au deposit is located in Hengxian County about 100 km southeast of Nanning City in the very southern part of the Dian-Qian-Gui area in Guangxi District near the town of Hengxian at E 109° 1' 05", N 22° 37' 40". Access is approximately 15 km southeast along river and then from the south side of the river by road south about 20 minutes inland. The topography is low hills with rich tropical vegetation in intensely weathered terrane. The district is 7.7 km long from east to west and 1.7 km wide from north to south. The deposit was visited during 1997 and information is from that visit and laboratory investigations and from the 4th Geologic Team of the Guangxi Bureau of Geology. Geological work on this deposit has developed about 9.34 tonnes Au of proven reserve.

Oxide ore is mined from 6 separate northeast-striking, moderately south-dipping ore zones that have an over all strike length of >1 km. An open pit mine is developed on zones No. 1 and No. 2 using drilling, blasting, and hauling in 8 tonne dump trucks loaded by backhoe (fig. 3-47). Ore is trammed to cyanide vats where it is processed (figs. 3-48, 3-49). Hanging wall zones lie along the slopes or bottom of the adjacent valley and are partially hidden by valley fill (fig. 3-47).

Figure 3-47. Photographs of Nanxiang (Hengxian) Au deposit area, Guangxi District, Dian-Qian-Gui area. (*A*) Broad view of valley where vat processing is taking place. Nos. 3, 4, 5 and 6 zones lies in the valley. No. 2 zone in the foreground parallel and under road system. (*B*) Main No. 1 zone fault area (in notch) and foot wall of orebody in main open pit.

Figure 3-48. Photograph of unloading of cyanide and lime from river dock near the Hengxian Au deposit, Guangxi District, Dian-Qian-Gui area. Workers cover themselves in plastic sheets to prevent contact with the chemicals in the humid environment.

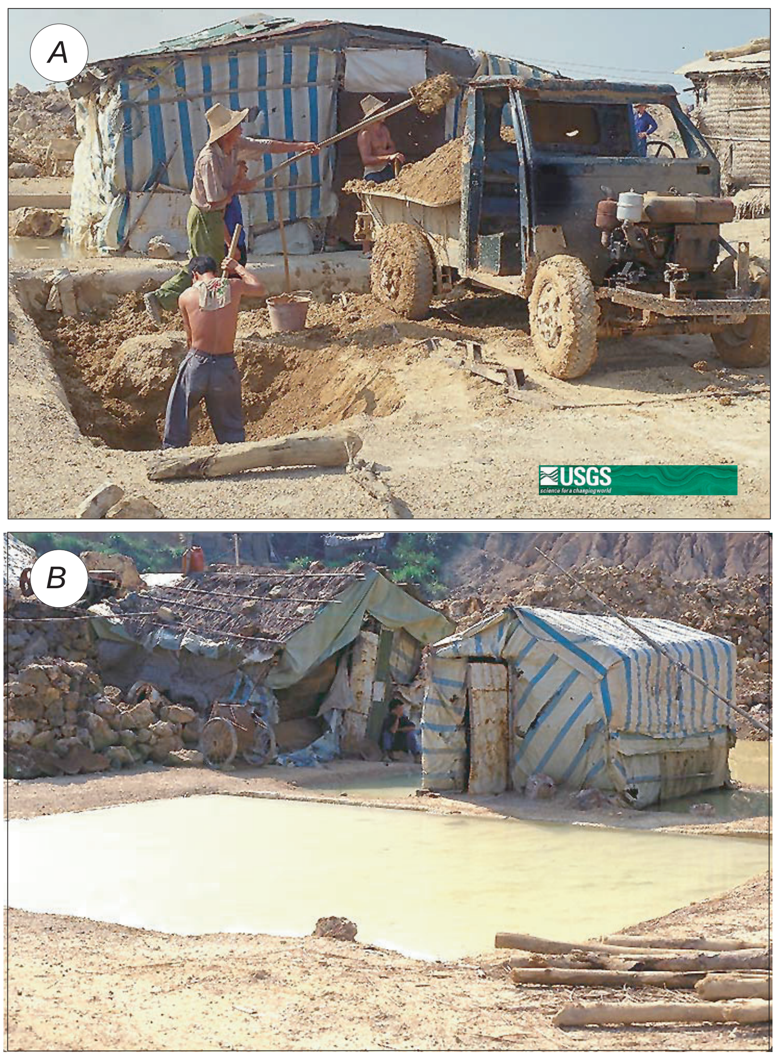

Figure 3-49. Photographs of vat leach process in the Hengxian Au mine, Guangxi District, Dian-Qian-Gui area. (*A*) removal of leached ore by hand from vat (*B*) Fully-filled vat with pump house in back ground.

The Hengxian Au deposit zone is 3.0 km long and 0.8 km wide and trends northeast. The deposit contains 5 main orebodies that are lenses and tabular shaped. Ore bodies are strictly controlled by faulting and internal silicified zones with additional interformational silicified zones that dip southeast (150 to 155°) at angles of 10 to 87°. The main ore bodies are present along a major fracture zone that dips to the southeast at 70 to 85°. Small orebodies are present in interformational fracture zones and dip southeast at angles of 10 to 35°. The main orebody is 50 to 61 m long, 10 to 16 m wide and extends from 40 to 264 m deep. Average grade is 4.6 g/t Au.

The footwall No. 1 ore zone is localized along a faulted contact between Cretaceous sedimentary rocks in the hanging wall and Cambrian sedimentary rocks in the foot wall (figs. 3-47, 3-50 and 3-51). The Hengxian No. 1 mineralized zone usually is less than 15 m wide and contains silicified clast-breccia (fig. 3-52). The breccia is mineralized with pyrite, stibnite, and barite. The ore grades between 0.3 and 4.3 g/t Au. All six orebodies trend approximately northeast 70° and dip south at about 70 to 80°. The main host rock is the Cretaceous siltstone, sandstone of the fault's hanging wall.

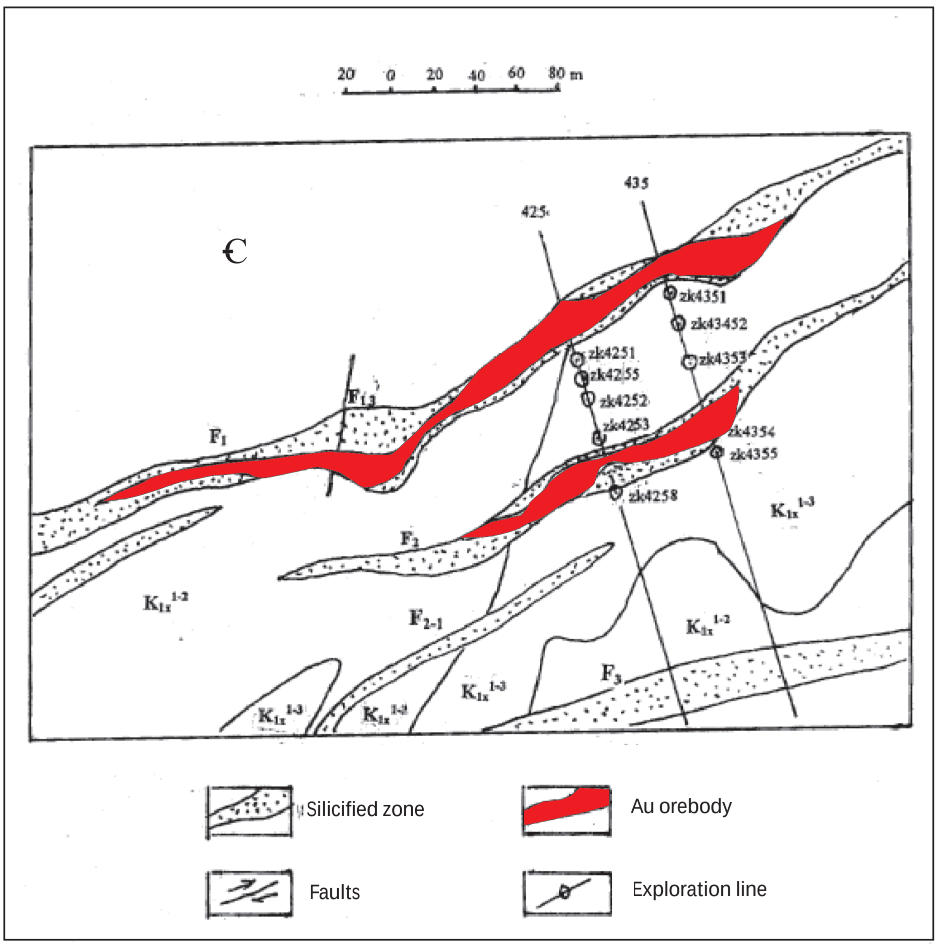

Figure 3-50. Geologic sketch map of the Hanxiang (Hengxian) Au deposit, Guangxi district, Dian-Qian-Gui area. Orebodies are present along northeast-striking faults between Cambrian (C) and Cretaceous (K) sedimentary rocks and in parallel faults in the Cretaceous rocks. Sections 425 and 435 are portrayed on figure 3-51. Modified from the No.4 Geologic Team of Guangxi. For longitude and latitude, see text and Appendix III.

Strata exposed in the Hengxian deposit are Cambrian, Carboniferous, Cretaceous and Quaternary sedimentary rocks. Gold-hosting horizons are the lower member of the lower Cretaceous Xinlong Formation (K_1x^1), which is composed of lagoonal facies sedimentary rock and is divided into three sub members:

(1) K_1x^{1-1}, the 60– to 100–m-thick upper section, composed of detrital mudstone, arenaceous mudstone, and conglomeratic argillic sandstone;

(2) K_1x^{1-2}, the second 80– to 100–m-thick sub member, composed of mudstone, argillic siltstone, fine-grained sandstone, and siltstone in three cyclothems; and

(3) K_1x^{1-3} the >60 m thick sub member, composed of arenaceous conglomerate, conglomeratic sandstone interlayered with sandstone and arenaceous mudstone. The lower parts of this sub member are composed of Fe–Mn-bearing argillic conglomeratic sandstone, and arenaceous mudstone.

Main structures in the Hengxian Mine area are faults. There are four normal faults in the area that control ore (figs. 3-50, and 3-51):

(1) the 7,400–m-long, 28– to 170–m-wide F_1 fault that contains the No. 1 silicified fracture zone and strikes NE70° and dips to the southeast at angles between 75 and 87°;

(2) the 3,600–m-long, 15– to 40–m-wide F_2 fault that contains the No 2 silicified zone and strikes NE60° and dips so the southeast at angles between 70 to 85°;

(3) the 1,200–m-long, 8– to 56–m-wide, F_3 fault, hosting the No 3 silicified zone and striking NE65° and dipping at an angle of 84°; and

(4) the 1,000–m-long, 2– to 18–m-wide F_{2-1} fault hosts the No 2-1 silicified zone, is located between the F_2 and F_3 faults and strikes NE65°.

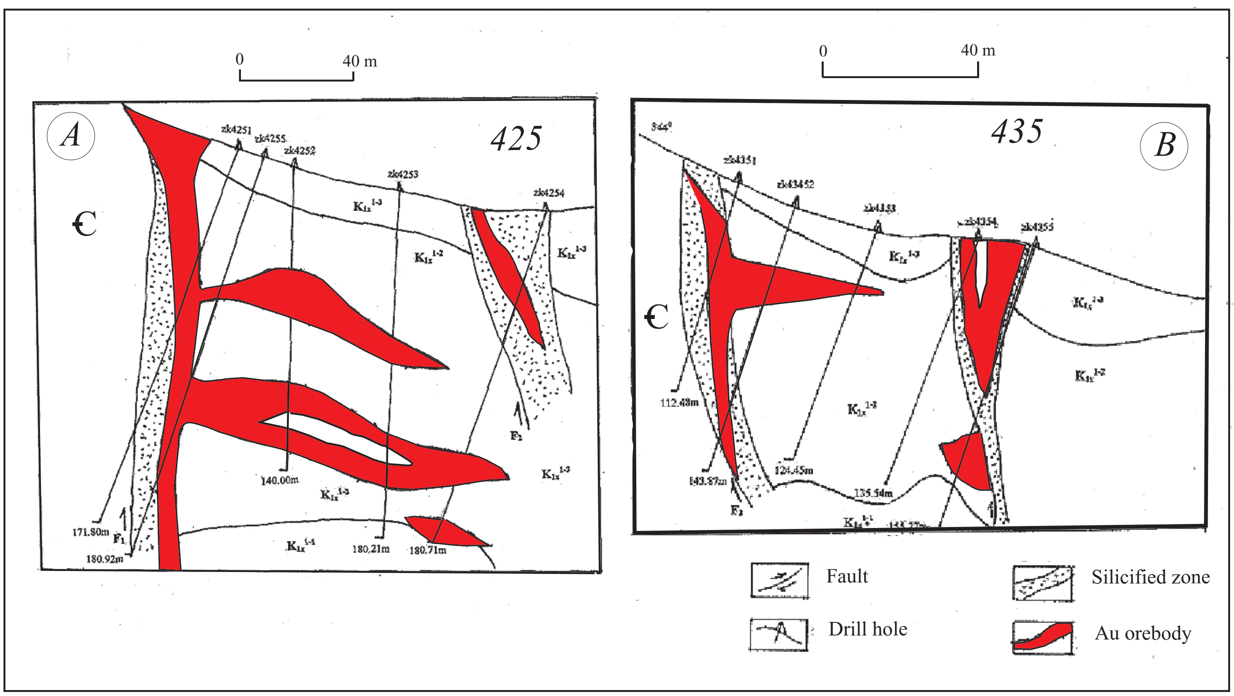

Figure 3-51. Geologic cross sections of the Nanxiang (Hengxian) Au deposit, Guangxi District, Dian-Qian-Gui area, looking northwest. Orebodies are present along northeast-striking faults between Cambrian (C) and Cretaceous (K) sedimentary rocks and in parallel faults in the Cretaceous rocks. (*A*) Section 425 showing multiple stratabound oreshoots in Cretaceous rocks. (*B*) Section 435, showing single stratabound oreshoot and parallel orebody to the south. Location of sections shown on figure 3-50.

Hydrothermal alteration is widespread in the four main mineralized and silicified zones. The main alteration type is silicification and is accompanied by the addition of pyrite and carbonate. There are four types of Au ore: (1) hydrothermal quartzite Au ore; (2) silicified sandstone Au ore; (3) silicified argillic siltstone-silicified silty mudstone Au ore; and (4) silicified breccia Au ore. Ore minerals mainly are limonite, pyrite, and native Au, as well as stibnite, molybdenite, chalcopyrite, and galena. Gangue minerals are quartz and sericite, as well as zircon, leucoxene, muscovite, kaolinite, barite, and calcite. Quartz, pyrite, and jarosite are the main carriers of Au that is present as small spherulitic and crevassed grains in micro cracks and inclusions. Gold mainly is native Au in 0.016 to 0.2 mm-size grains. Gold also is present as absorbed Au in hypogene pyrite rims.

Geochemically, the Hengxian Au deposit oxide ores are anomalous in Sb, Te, and Tl and contain moderately elevated concentrations of As, Hg, Cu, Pb, Se, and Zn (Appendix IV). This geochemical signature may be somewhat masked by supergene processes, but is compatible with, but not completely diagnostic of Carlin-type Au deposits. The elevated concentrations of Ag (5 to 45 ppm) and Pb are higher than those in the other sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area. In addition, lower concentrations of Zn, As, and Ni differ in the

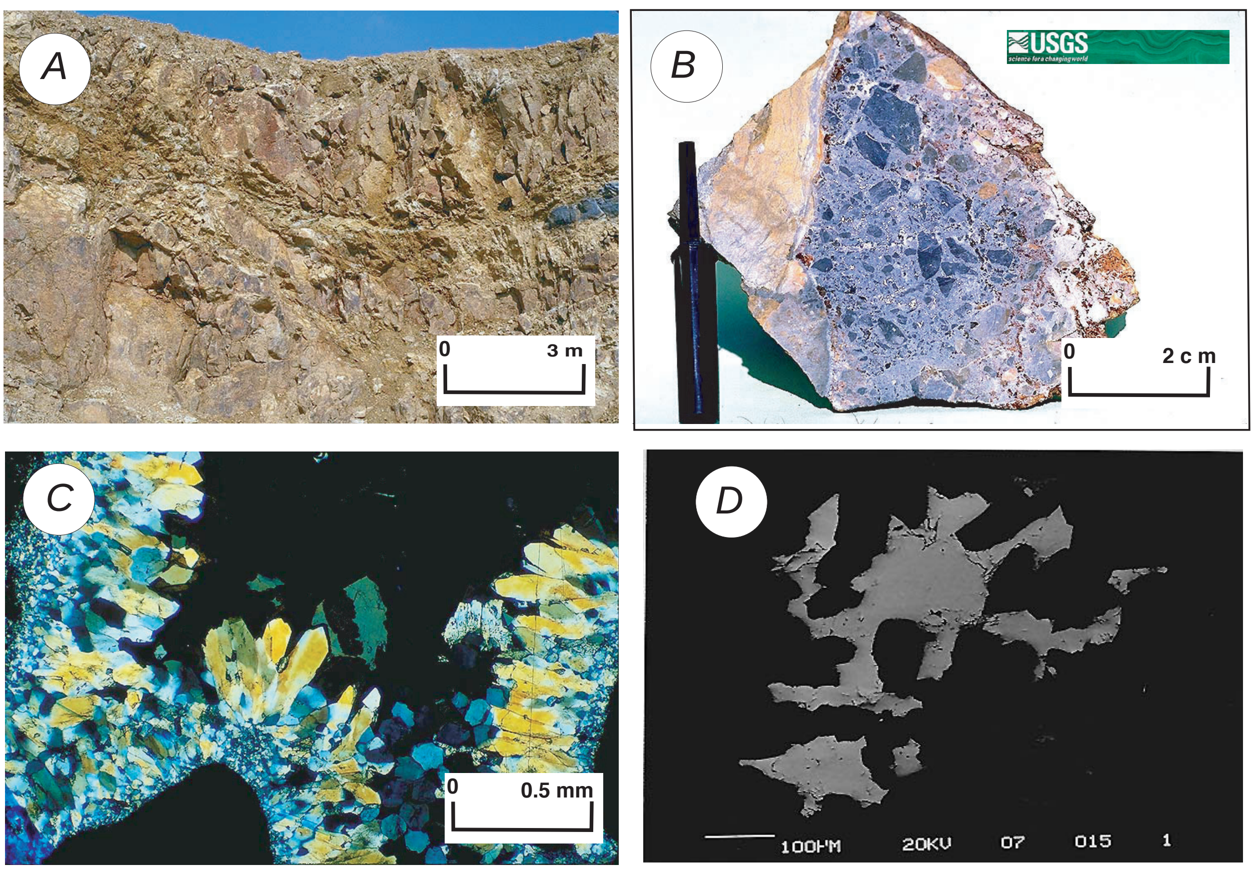

Figure 3-52. Photographs of ores and ore minerals in the Gaolong Au deposit, Guangxi District, Dian-Qian-Gui area. (*A*) Mine bench, parallel to the main orebody. Note shearing in bench walls. (*B*) Slabbed quartz-stibnite-pyrite breccia. (*C*) Microphotograph of very fine-grained comb quartz in silicified zone. (*D*) Scanning electron microscope (SEM) back scatter image of stibnite encased in quartz in breccia.

Hengxian Au deposit compared to the rest of the region. On the basis of the geochemical signature and younger host rocks, the Hengxian Au deposit may reflect a separate type of system to other Carlin-type Au deposits in the Dian-Qian-Gui area.

DISCUSSION and CONCLUSIONS

The sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area share many similar characteristics, particularly mineralogy, geochemistry, host rock, and structural control (Yao, Z.G., 1990). Most of the deposits are associated with structural domes, stratabound breccia bodies, unconformity surfaces or intense brittle-ductile structural zones (see also, Zheng, M.H., 1989, 1994; Deng, X.N., 1993; Liu, D.S. and others, 1994).

The Au deposits in the Lannigou Au deposit district are hosted in early Permian to middle Triassic sedimentary rocks that may have Au-bearing source rock potential according to Zheng, Q. and Zhang, M. (1989) who documented that siltstone and argillite contain an average of 20.37 ppb to 17.40 ppb Au. These geochemical values are much higher than in adjacent rocks, indicating that the Au may have pre-dated structural disruption and hydrothermal alteration. Carbonaceous rocks have been suggested as source-beds for petroleum, Hg, and Au deposits (Li, Y.D. and Li, Y.T., 1994; Zeng, Y.F. and Yin, H.S., 1994).

The Lannigou Au deposit is considered by Lou X.H (1994, 1996) to have formed during an 83 Ma event that produced fault zones at the same time that the hydrothermal fluid was introduced (see also, Zhang, F., and Yang, K.Y., 1993). Multiple periods of structural activity in the presence of the ore fluid allowed the ore zones to thicken and become enriched. Ore-forming materials were remobilized, moved, and concentrated in the favorable structures. As a result, many deposits, prospects, and anomalies are present surrounding the Laizishan dome. Both host structures and Au mineralization are coincident in space and likely are coeval in many locations. This model is applicable to many nearby deposits, especially the Yata and Banqi deposits.

Some host structural zones of sedimentary rock-hosted Au deposits along the Carlin trend are interpreted by Peters and others (1998, 2000) and Peters (2000a,b) to act as brittle-ductile, fluid-filled shear folds that contain deformed, broad, 200–m-thick zones with multiple, sheared strands, breccia bodies, and internal phacoidal-shaped blocks and slabs. Deformation in Nevada and in the Dian-Qian-Gui area along regional-scale conduits and crosscutting deformation zones may have been synchronous with Au transport and deposition.

Sedimentary rock-hosted Au mining districts are known to lie along belts (Roberts, 1960, 1966), or are associated with regional-scale lineaments (Shawe, 1991). Belts and lineaments are compatible with genetic theories of ore formation, which call for deep-seated, over-pressured fluids and associated conduits (Kuehn and Rose, 1995; Lamb and Cline, 1997). Alignment of these and other Au ore deposits has been suggested by Shawe (1991) to be an important factor in producing the large number of gold deposits in Nevada (see also, Teal and Jackson, 1997).

Lineaments, similar to the Youjiang fault zone have been postulated elsewhere to be conduits for deep-sourced metal-bearing fluids (Kerrich, 1986; Kerrich and Kyser, 1994) and may interact with these fluids near or in the ore depositional environment (Phillips, 1972, 1986; Sibson, 1994; Drew and others, 1996). Because most host rocks in the sedimentary rock-hosted Au deposits contain carbonate minerals, dissolution—associated with hydrothermal fluid flux and alteration—is common along and adjacent to the regional-scale conduits that connect them. Evidence suggesting that Au deposition was synchronous with tectonic movement in the Dian-

Qian-Gui area includes: (1) clustering of deposits along trends; (2) deformation textures in some ores; (3) high ore fluid pressures indicated by fluid inclusion investigations and some ore textures; and (4) coincidence of intensely deformed zones with alteration and(or) mineralization. These geologic features support a hypothesis that formation of many of the sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area was synchronous with brittle-ductile deformation.

ACKNOWLEDGEMENTS

The authors would like to thank the numerous geologists and officials who facilitated our 1997 and 1999 field visits to deposits in the Dian-Qian-Gui area. Among these are Chief Chen and Xin Xunfeng, Guizhou Bureau of Geology and Mineral Resources; Lin Jianhui, Zhou Shangguo, Nanning Geological Survey, Guangxi, Ministry of Metallurgical Industry), Zhang Fuyong and Shen Wanjun, Guizhou Gold Bureau, Tang Reiwei, Gold Management Bureau of Guizhou, and Wu Guogang, Director Mineral Resources Bureau and Gold Bureau, Funing County, Yunnan Province. Mr. Li Yong Ming translated some geological materials. The manuscript benefited from review by Charles G. Cunningham.

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