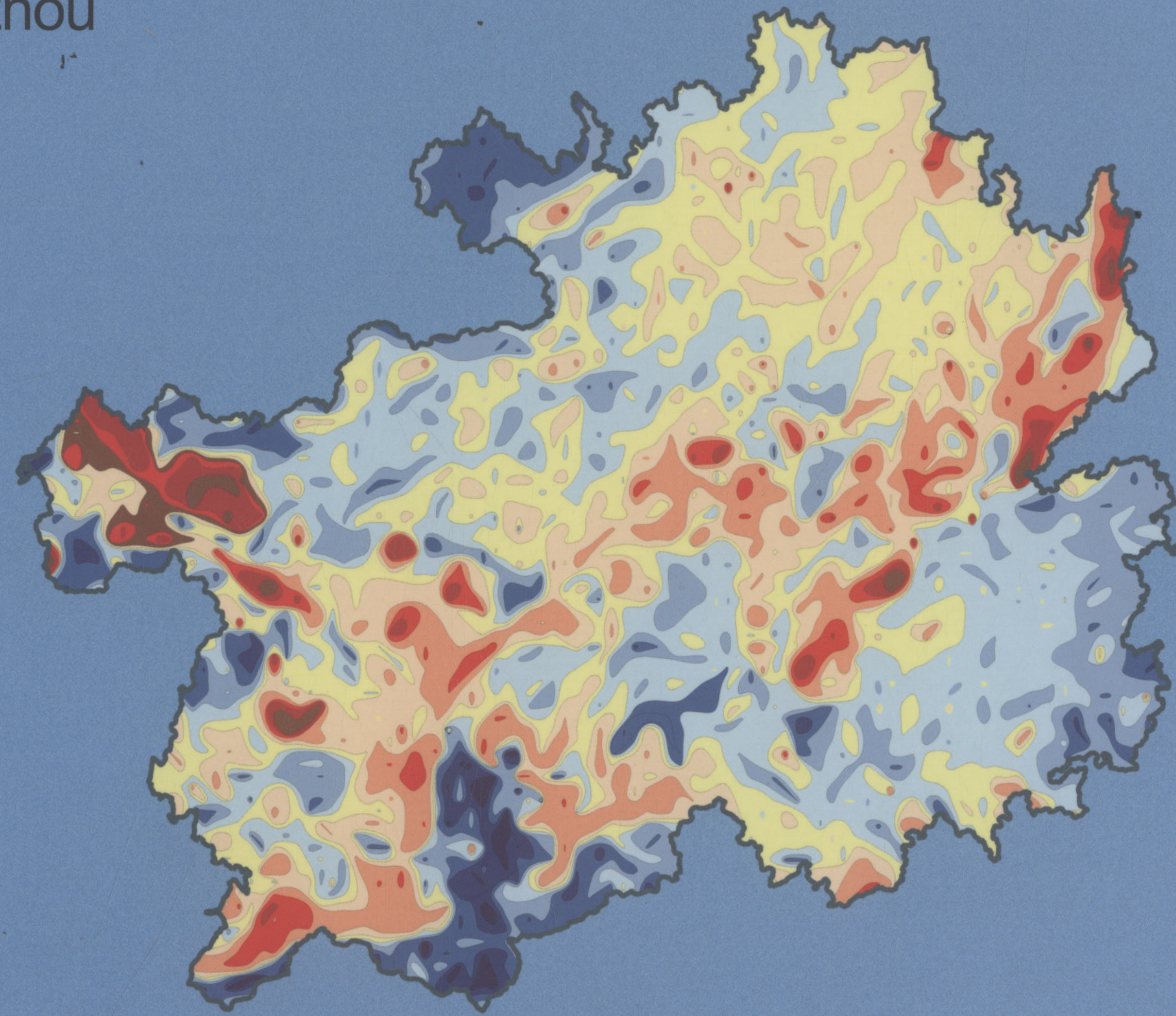
GEOCHEMICAL ATLAS IN GUIZHOU PROVINCE, CHINA

Guizhou Bureau of Geology and Mineral Resources
Chief Editor: FENG Ji-zhou



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Preface

The development of biology has gone through a course from study of organs, then to cells and finally to genes which are the ultimate unit for living things. Research on genes makes biology revolutionized and developed by leaps and bounds. At present, geology is being faced with basic tasks to solve problems on resources and environment. Elements and isotopes are the basic constituent of mineral resources, while environmental problems are related to the behavior and distribution of elements and their chemical compounds. Element is the ultimate unit in geo-science research. More or less to say, a geochemical element map of the unliving earth surface is analogous to a gene diagram of living things. Geochemical maps on all scales will make contribution of inestimable importance to the research and development of geosciences and play a predominant supporting role in the solution of mineral resources and environmental problems.

Over the past 30 years, China's Regional Geochemistry—National Reconnaissance Project (RGNR) has covered more than seven million square kilometers of territory which leads to China having the most remarkable nation-scale geochemical database in the world. It is a pity that up to now, any standard geochemical atlas in English has not been published in China. The publication of "Geochemical Atlas of Guizhou Province, China" is a forerunner in this respect. It is expected that beginning with this atlas, more and more geochemical atlases will be published in China, pushing the tremendous amount of China's geochemical mapping information to the world.

Geochemists in Guizhou province have developed method and techniques for geochemical mapping in Guizhou's karst environment. A lot of large and significant anomalies were delineated which led to many new deposit discoveries in Guizhou. The most exciting success is the discovery of the world-class Lannigou gold deposits through hard work of follow-up surveys and drilling works by Guizhou's geologists and geochemists. Lannigou gold deposit and other gold deposits in SW Guizhou have constituted the second large Carlin-type gold camp in the world (next only to the Carlin-type deposits in Nevada, USA). Their success not only demonstrated the important role of geochemical mapping in mineral exploration in Guizhou, but also promoted the implementation of geochemical mapping in other provinces of China.

Xie Xuejing

2009. 8. 28

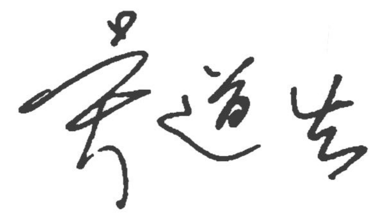
Congratulations on the Publication of the Geochemical Atlas in Guizhou Province

Geochemical maps are fundamental results of geochemical mapping. Geochemical Atlas in Guizhou Province is a very valuable fundamental geological material which was crystallization of wisdom and the fruits of labour of exploration geochemists from Guizhou Province over the past more than 20 years. It may be widely applied to fundamental geology, environmental science, agricultural science and medical science. It fully reflects the geochemical characteristics of different geological settings within the boundaries of Guizhou Province and clearly shows the distribution of strata, magmatic rocks and major structures. The major metallogenic zones, metallic orefields and large, medium and some small ore deposits fall into the related geochemical anomalies. It will certainly bring into full play to the research on geosciences and related sciences in Guizhou Province.

Guizhou Province is characterized by the development of karst landscape where geochemical mapping can use no experience of other countries for reference. Exploration geochemists from Guizhou successfully solve the problems of methodology and technology for geochemical mapping in the karst landscape region which makes geochemical mapping in Guizhou Province very successful. Geochemical mapping in Guizhou Province achieves good results, making an important breakthrough in gold exploration.

On the occasion of publication of "Geochemical Atlas in Guizhou Province, China", we are very grateful to exploration geochemists from Guizhou Province for their experiencing all kinds of hardships and making tremendous efforts. I avail myself of this opportunity to renew to them the assurances of my highest consideration!

WU Dao-sheng



Secretary, Communist Party Committee
Guizhou Bureau of Geology and Mineral Resources

Acknowledgment

The achievements of geochemical exploration in Guizhou Province over the past more than 20 years should be attributed to hundreds of field geochemists, analysts and IT engineers from several organizations. Field geochemists traveled over difficultly accessible regions, one of them even gave his life, in order to collect high quality samples. Their unselfish tribute is responsible for the tremendous amount of high quality information obtained which will be utilized though many years to come.

Geochemical Atlas in Guizhou Province is compiled from analytical data for 39 elements of composite stream sediment samples (1 composite sample per 4 km^2). Though study and widespread application of these data could be of great importance to mineral exploration, study of fundamental geology, environment monitoring and protection in Guizhou Province.

Thanks are given to Wu Daosheng, Secretary of the Communist Party Committee of the Guizhou Bureau of Geology and Mineral Resources (GBGM), Zhu Lijun, Director of the GBGM, Du Guohua, Director of the Research Institute of Geophysical and Geochemical Exploration of the GBGM, for their support and guide. Thanks are also given to Han Zhijun, former Director and Chief Geologist of the GBGM, Wang Yangeng, former Assistant Chief Geologist of the GBGM, Li Xingsen, Assistant Chief analyst of the Central Laboratory of the GBGM and Professor Guo Zhenchun, Department of Geology and Mineral Resources of the GBGM for their comments and criticisms on the manuscript.

We are very grateful to Prof. Xie Xuejing, Member of the Chinese Academy of Science for his consistent help in sampling, analysis, map compilation and publication of this Geochemical Atlas.

Editor

2009. 8. 28

Contents

Introduction

The Regional Geochemistry—National Reconnaissance (RGNR) Program proposed by Prof. Xie Xuejing[1,2,3], was approved by the formal Ministry of Geology and Mineral Resources in early 1978. The 1 : 200 000 Geochemical Mapping Project in Guizhou Province was among some of the earliest subprogram, initiated in late 1978. The 1 : 200 000 Geochemical maps in Guizhou Province were compiled in succession during 1978—1998. The study of sampling, analysis data monitoring, data processing and map construction were carried out according to Prof. Xie's Monograph: Regional Geochemistry[2] and the RGNR Working Instructions "Some Regulations concerning working methods for Regional Geochemistry—National Reconnaissance (RGNR) Project"[4].

Due to the complexity of Guizhou landscape, more study of sampling was carried out by the Guizhou geophysical and Geochemical Exploration Team[5]. The all-round implementation of the 1 : 200 000 mapping project in Guizhou was by No. 109 Geophysical and Geochemical Exploration Team, together with No. 108, No. 101 and No. 103 Geological Survey Teams. All belong to the Guizhou Bureau of Geology and Mineral Resources. 233810 samples were collected within an area of 18 020 km^2 with average sampling density of 1.22 samples/km^2. Samples from four 1km^2 unit cells were combined to make a composite sample for the analysis of 39 elements: Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cu, F, Hg, La, Li, Mo, Mn, Nb, Ni, P, Pb, Sb, Sn, Sr, Th, Ti, U, V, W, Y, Zn, Zr, SiO_2, Al_2O_3, Fe_2O_3, K_2O, Na_2O, CaO and MgO.

Analytical data quality monitoring system developed by Prof. Xie[2,4,6] was used during routine analysis to strictly monitor the analytical accuracy and precision. Contour maps were constructed based on the MapGIS and GeoMDIS software[7].

The application of the results of the geochemical mapping to mineral exploration has achieved great success. The most exciting of these was the discovery of the second large Carlin-type deposit cluster in the world.

The Geochemical Atlas in Guizhou Province will certainly bring into full play to the fundamental geological and metallogenic study, resources potential prediction, mineral exploration, assessment of environment and land quality in Guizhou Province.

I Geological setting

Geochemical mapping studies the spatial distribution of chemical elements and in the Earth's crust, taking rock, soil, stream sediment and water as medium of study which have a close relation to the geological setting in which they lie.

Guizhou Province (Fig. 1) lies in the south China plate where the Tethyan tectonic domain and marginal-Pacific tectonic domain intersect[8,9,10]. The Earth's crust in Guizhou Province is typically continental with mosaic structure framework consisting of strongly deformed zones and weakly deformed domains. Isotopic dating indicates that the oldest rock in Guizhou Province gives an isotopic age of more than 1400 Ma. In the past long geological history, Guizhou went through many geological events and was subjected to multiple tectonism which brought up its picture today. Prior to the Triassic, Guizhou geology was controlled by the formation, development and consumption of the Tethys and since the Jurassic, it was under the influence of subduction of the marginal-Pacific plate.

1. Geotectonic features

Tectonically, according to Wang Yangeng et al., Guizhou Province may be divided into upper Yangtze landmass, Jiangnan orogenic zone and Youjiang orogenic zone[8,9,10] (Fig. 2).

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Fig. 1 Location of Guizhou Province in China

Fig. 2 Geotectonic division in Guizhou

(from Wang Yangeng, 1992, 1996)

Yz—Yangtze landmass; Jn—Jiangnan orogenic zone; Yj—Youjiang orogenic zone; B—Boundary of tectonics

1.1 Upper Yangtze landmass

Guizhou lies in the southwest of the upper Yangtze landmass which occupies a large part of Guizhou Province. The basement consists of Neoarchean-Early Proterozoic crystalline rocks, and Middle and Late Proterozoic metamorphic rocks, and the cover consists of Late Sinian to Late Triassic thick marine carbonate rocks which are characterized by giant Jura-type folds. The Himalayan orogeny and planar uplifting have been still going on.

1.2 Jiangnan orogenic zone

The southwestern sector of the Jiangnan orogenic zone extends into southeast Guizhou. It consists mainly of Paleozoic orogeny. The crystalline basement is unexposed. The metamorphic basement consists of the Neoproterozoic to Early Paleozoic epimetamorphic siliceous terrigenous detrital sediments. The sedimentary cover is poorly developed which consists mainly of the Paleozoic carbonates. This orogenic zone is characterized by complicated tectonic deformation with well developed fault zones.

1.3 Youjiang orogenic zone

Southwest Guizhou lies in the north of the Youjiang orogenic zone which was controlled by both Tethys and marginal-Pacific plate. The basement in the Youjiang orogenic zone is similar to that in the Jiangnan orogenic zone. Sedimentary cover consists mainly of the thick Middle Triassic terrigenous detrital sediments (flysch). Strong deformed folding was developed during the Indo-Chinese-Yanshanian period.

2. Stratigraphy

Strata from the middle Proterozoic to the Quaternary are completely exposed in Guizhou[10] with the total thickness of more than 30000 m. The strata in west Guizhou are younger than those in east Guizhou. The strata from Middle-Neoproterozoic through Paleozoic-Lower Mesozoic and Middle-Upper Mesozoic to Cenozoic change from marine siliceous terrigenous detrital sediments through marine carbonate to continental detrital sediments. The Middle and Upper Proterozoic consist mainly of marine detrital sediments. The Paleozoic and Lower Mesozoic consist mainly of marine carbonate. The Middle Triassic is composed of terrigenous detrital sediments. The strata from the Cambrian to the Lower Permian yield the Tethyan biota and Australia-Pacific biota. The Upper Permian yields Cathaysian flora. The marine Triassic is rich in Tethys-Yangtze fauna.

Marine carbonate rocks including limestone and dolomitite are widely exposed in Guizhou, covering about 61% of total area of this province. They contain higher CaO (on an average of 48.93%)[10]. Some limestone contains CaO as high as 55% which is approximated to the calculated value[10]. The strata from the Upper Sinian to the Middle Triassic in the Yangtze stratigraphic region consist mainly of carbonate rock dominated by organic limestone. Limestone breccia as gravity flow deposit was well developed in the Permian and Middle Triassic. Dolomitite as evaporite was developed in the Middle and Upper Cambrian and the Lower Triassic.

Another kind of important sedimentary rocks to Guizhou is marine siliceous detrital sediment which dominates over continental siliceous detrital sediment. The latter was developed after the Middle Late Triassic. Abyssal deposit was well developed in marine siliceous detrital sediments. Siliceous detrital turbidite was well developed in the upper Middle Proterozoic and the middle Upper Proterozoic in the upper Yangtze-landmass, and in the Middle and Upper Triassic in the Youjiang orogenic zone.

Pyroclastic rock such as tuff and sedimentary tuff occurs in the Late Paleozoic and Mesozoic marine formation. The tuff in Guizhou occurs mostly in the Upper Permian and Lower and Middle Triassic, secondly in the Lower Cambrian and Upper Devonian. The tuff between the Lower and Middle Triassic is called "mung bean rock". The "mung bean rock" and tuff in the lower Upper Permian Emeishan basalt and Dalong Formation are relatively widespread. The pyroclastic rock rich in micro elements which has a large effect on epigenetic geochemical process.

3. Igneous rock

Igneous rocks, consisting of time-various ultrabasic, basic, intermediate and acid extrusive and intrusive rock, are scattered[10], only covering about 2% of total area of Guizhou.

Volcanic rock is dominated by marine basic volcanic rock which may be divided into oceanic tholeiite series and continental tholeiite series[10]. The Permian Emeishan basalt having a great effect on epigenetic geochemical process is widely exposed in west Guizhou with an area of about 3200 km^2, and a thickness of 1249 m in the west and thinning in the east. Petrochemically, the Emeishan basalt is a Ti-high basalt characterized by enrichment in Ti and Fe and depletion in Mg and moderate Ca, K and Na.

Intrusive rockmasses are poorly developed in Guizhou. Both mantle- and crust-derived intrusive rockmasses are exposed in Guizhou. They were emplaced mainly in the Middle Proterozoic and Neoproterozoic and Late Permian, secondly in the Early Paleozoic and Mesozoic. Granitic rockmasses occur as stock, dyke and batholith in the Fanjing Mountain area, northeast Guizhou and in the Guizhou-Guangxi border region, Congjiang, southeast Guizhou. Alkaline ultramafic intrusions occur as dyke in the Neoproterozoic and Lower Paleozoic, especially, in the Cambrian Loushanguan Group, in southeast Guizhou and as dyke swarm and pipe in the Triassic in southwest Guizhou. Diabase sills as hypabyssal basic intrusion related to the Emeishan mantle plume occur in the Carboniferous and Permian in northwest and southwest Guizhou.

4. Metamorphic rock

Metamorphism within the boundaries of Guizhou, including regional metamorphism, thermal contact-metamorphism and dynamic metamorphism, took place mostly in the Precambrian and Caledonian epoch[10]. The regional metamorphism was well developed. The Middle Proterozoic Fanjingshan Group and Neoproterozoic Xiajiang Group and Banxi Group which are widely exposed in east Guizhou were subjected to greenschist facies regional metamorphism characterized by widespread development of sericite-chlorite alteration and well preservation of sedimentary texture and structure. Epimetamorphic rock such as metapelite, metaclastics and metapyroclastic rock (metatuff) has the greatest thickness. Dynamic metamorphism-dominant regional metamorphism is, in general, related to orogenic movement, degree of metamorphic strengthens with stratigraphic sequence. Some regional metamorphic zones were superimposed by biotitization.

5. Structure

Geological records indicate that since the Proterozoic, Guizhou has undergone at least 5 orogenesi, i. e. Sibao, Caledonian, Indo-Chinese, Yanshanian and Himalayan orogenesis[10].

Surface structure in Guizhou was fell into its pattern in the Mesozoic and reformed in the Cenozoic, becoming typical thin-skinned structure. According to deformation and structural style, Guizhou may be divided into 4 structural belts: Hubei-Chongqing-Guizhou Jura-type fold belt (Ⅰ), Jiangnan fold-fault belt (Ⅱ), Nanpanjiang fold belt (Ⅲ) and Sichuan basin-marginal broad fold belt (Ⅳ). The Hubei-Chongqing-Guizhou Jura-type fold belt (Ⅰ) may be subdivided into 3 second-order structural deformed subbelts[8,9,10] (Fig. 3)

The giant Jura-type folds consisting mainly of the Paleozoic wide-spaced, wide-spaced-like and box folds are well developed. The wide-spaced folds are the most typical. They consist of a series of tight synclines and broad anticlines parallel each other. Some thrust faults subparallel to the fold axis and strike-slip faults oblique to the fold axis are developed in some regions. These folds and thrust faults are characterized by horizontal zonation. In general, from southeast to northwest, strength of folding and faulting was reduced, folded strata were younger and fold style tended to wide-spaced style→wide-spaced-like style→dilatational wave style→box style, thrust faults reduced on a scale and quantity and were replaced by high-angle normal fault. A large amount of data indicate that it is a multiperiodic active complex fracture zone.

The NNE- and NEE-trending shear fracture systems were developed in the Proterozoic stratigraphic region in southeast Guizhou which lay in the western sector of the Jiangnan fold-fault belt. These shear fracture systems form a network structure. Regional cleavage (and slaty cleavage and so on) were widely developed in the stratiform epimetamorphic rock series in this zone, forming a transitional shear zone.

The southwest Guizhou lies in the Nanpanjiang fold belt of the Youjiang orogenic zone which consists of the Triassic detrital formation where folds and faults were well developed.

The north Guizhou lies in the Sichuan basin-marginal broad fold belt which consists of the Jurassic and Cretaceous red sandstone and shale characterized by weak deformation, moderately pitching, broad fold and undeveloped fault.

Ⅱ Mineral resources

Guizhou is rich in mineral resources[11]. 123 kinds of minerals and more than 3000 mineral occurrences have been

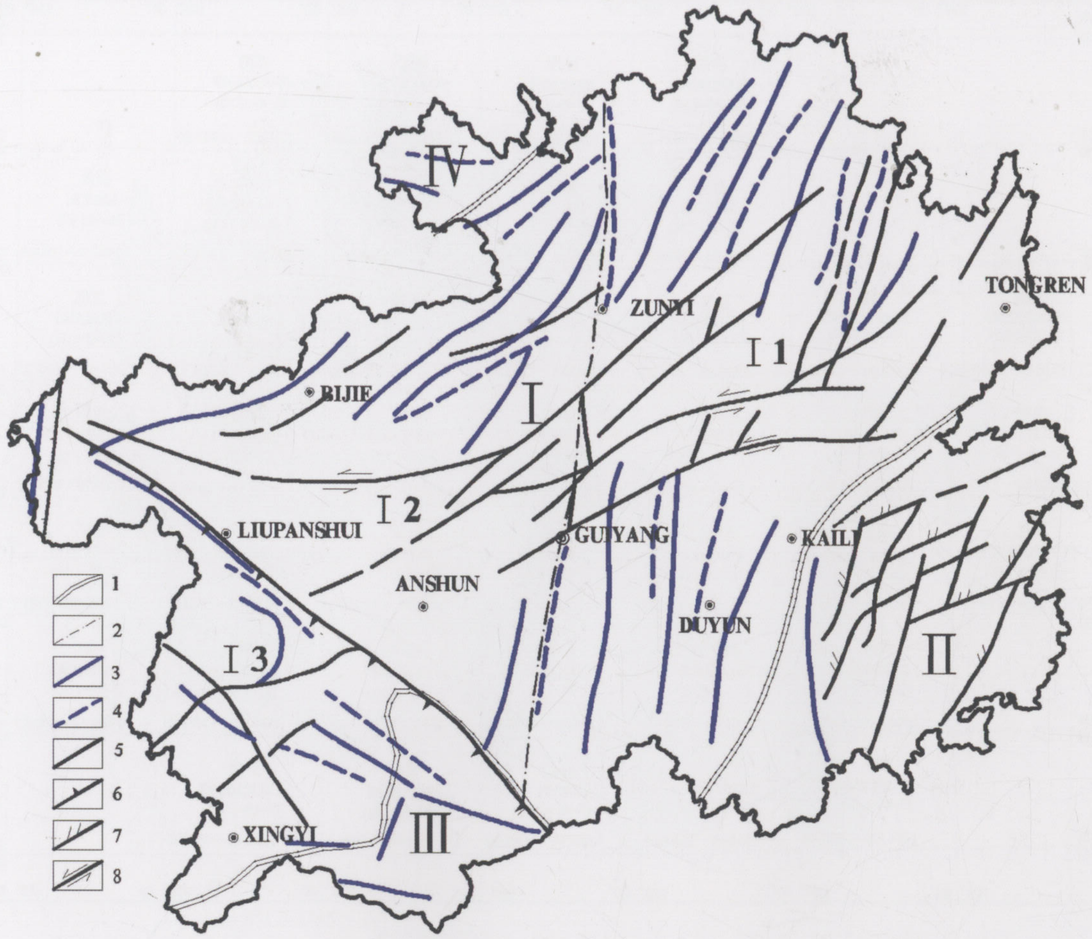


Fig. 3 Structural outline map in Guizhou

(Modified from Wang Yangeng, 1996)

Ⅰ—Hubei-Chongqing-Guizhou Jura-type fold belt, Ⅰ1—Wulingshan NNE-trending fold-thrust zone, Ⅰ2—Bijie - Anshun NE-trending deformed zone, Ⅰ3—Wumengshan NW-trending strike-slip deformed zone; Ⅱ—Jiangnan fold-fault belt; Ⅲ—Nanpanjiang fold belt; Ⅳ—Sichuan basin-marginal broad fold belt.

1—Boundary of tectonic belt; 2—Boundary of tectonically deformed region; 3—Anticlinal axis; 4—Synclinal axis; 5—Fault; 6—Thrust fault; 7—Shear fault; 8—Strike-slip fault

found in Guizhou among which 76 mineral resources and 1344 mineral occurrences have some reserves, and 41 mineral resources rank the first ten on available reserves (resources) in China.

Sedimentary and meso-epithermal ore deposits are of great importance to Guizhou. Geochemical exploration methods are mostly suitable for the meso-epithermal ore deposits.

Coal and coalbed gas, phosphorite, bauxite, manganese, barite, Au, Sb, Hg and so on, are the most important in the mineral resources in Guizhou.

Coal and coalbed gas are distributed over central and west Guizhou to the west of 108°E. The coal ranks the fifth in China and the first in 11 provinces to the south of the Yangtze River on available resources. The coalbed gas ranks the second in our country on reconnaissance resources.

Bauxite (and Ga) resources are mainly distributed over Guiyang region in which the Maochang giant bauxite deposit is situated and rank the third in our country on available reserves.

Phosphorite resources associated with iodine ore or REE in Guizhou rank the second in our country on available reserves with high-grade phosphorite ore of 4.5×10^9 t ranking the first in China. The reserves of large phosphorite deposits amount to more than 80% of the total reserves.

Manganese ore resources are mainly distributed over Zunyi and Songtao Counties and rank the fourth in our country on available reserves with medium deposits having more than 98% of the total reserves.

Barite ore ranks the first in our country on available reserves. The Tianzhu giant barite deposit has available reserves of about 10^8 t.

Gold resources rank the ninth in our country on available reserves. Carlin-type gold deposits in southwest Guizhou have constituted the second largest Carlin-type deposit cluster in the world, making up more than 95% of the total reserves in Guizhou.

Antimony resources rank the fourth in our country on available reserves.

Moreover, Guizhou is rich in magnesium-metal- producing dolomitite, chemical industry dolomitite and cement-producing nonmetallic mineral resources as well as Tl, Hg, Cd, As resources and so on.

Ⅲ Geomorphologic landscapes

Guizhou Province lies in the transitional zone between the Qinghai-Tibet Plateau and east China hills and plain. Generally speaking, the terrain of Guizhou Province slopes from west to east, forming three stair-steps[10] (Fig. 4). The first stair-step is plateau between Liupanshui and Bijie in west Guizhou with an elevation of more than 3000m to 1500m, and the second stair-step is mountains and hills in central Guizhou, with an elevation of 1500—1000 m, and the third stair-step is low hills in northeast and southeast Guizhou with an elevation of 800—400 m. Meanwhile, the watershed between the Yangtze River system and the Zhujiang River system lies in central Guizhou, making the terrain of Guizhou sloping both to north and to south.

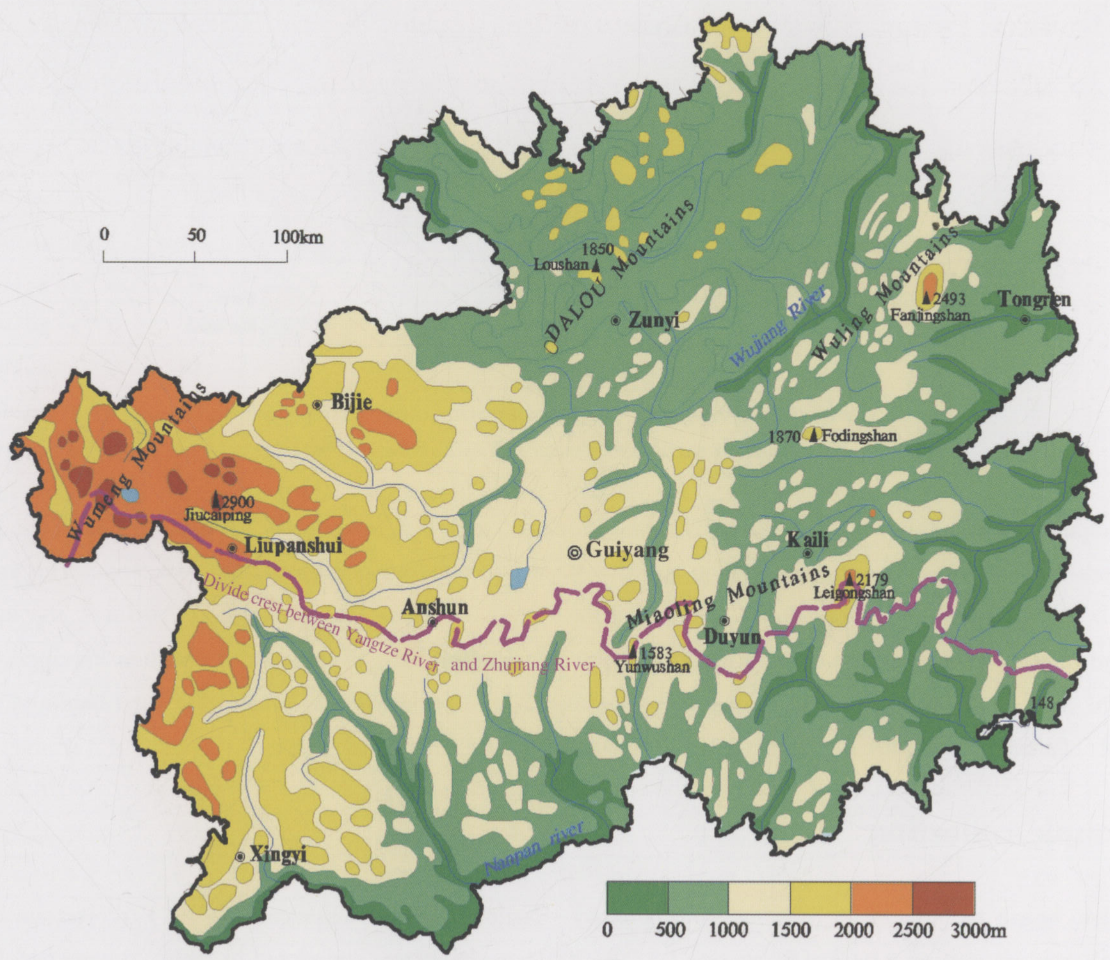


Fig. 4 Relief map of Guizhou

The terrain in Guizhou is characterized by great difference of elevation (2763 m) with the highest peak Jiucaiping, Weining having an elevation of 2901 m and the lowest Shuikou river valley, Liping having an elevation of 148 m. The different of elevation in some mountain areas is greater, for example, the difference of elevation in the Fanjing and Leigong Mountains areas is up to more than 700—1000 m.

The surface lithology of Guizhou can be divided into regions mainly with carbonate rocks (karst regions), and regions mainly with clastic rocks.

Guizhou lies in the subtropical zone, where limestone is widely exposed, with an annual precipitation of 1100—1300 mm which results in the widely development of denudation-erosional land form and corrosional land form dominated by karst land form(Fig. 5).

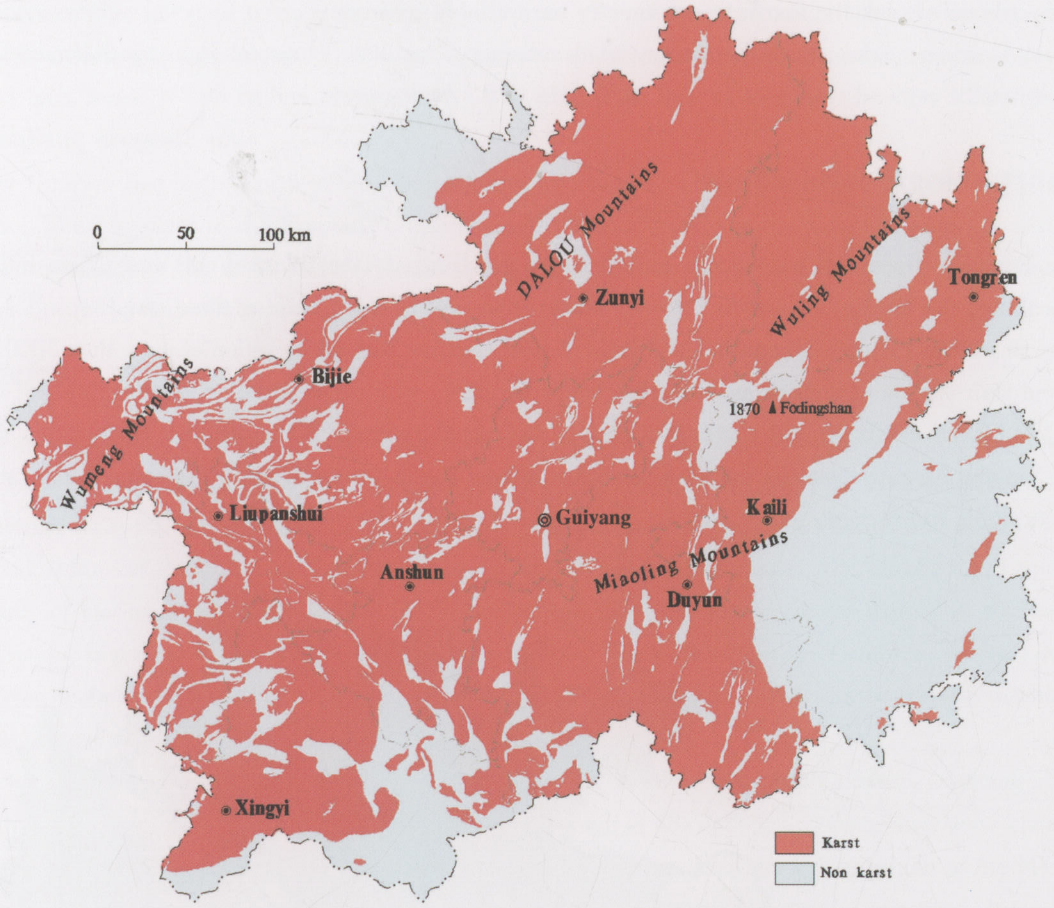


Fig. 5 Distribution of karst landform and non-karst (clastic) landform in Guizhou

(Modified from Regional Geology of Guizhou Province, 1987)

Carbonate rock is widely distributed over Guizhou Province, with the exception of the Middle and Upper Proterozoic epimetamorphic rock area in southeast Guizhou and the Meso-Cenozoic terrigenous detrital rock area. The area of pure carbonate rock in Guizhou is 109084 km^2, accounting for 61.9%[8] of the area of Guizhou Province, the total area of impure and pure carbonate rock is about 130000 km^2, accounting for 73% of the area of Guizhou Province. The karst landform in Guizhou is one of the most typical karst landform in the world with the area of the karst landform making up about 12% of that in China.

IV. Sample collection

Guizhou began to implement Regional Geochemistry—National Reconnaissance (RGNR) Project in 1978. The field sampling work covered a total of fourty one 1∶200 000 map sheets was completed in 1992. Among which there are 17 full map sheets and 24 cross-province map sheets(Fig. 6). A total of 233810 samples were taken for analysis, among which there are: 219020 basic samples and 14790 duplicate samples. 824 primary standard reference samples (GSD) and 4250 secondary reference samples (GRD).

1. Preparation works

1.1 Preparation of primary standard reference samples (GSD1—12)

Twelve samples were collected and prepared by the Institute of Geophysical and Geochemical Exploration[12,13].

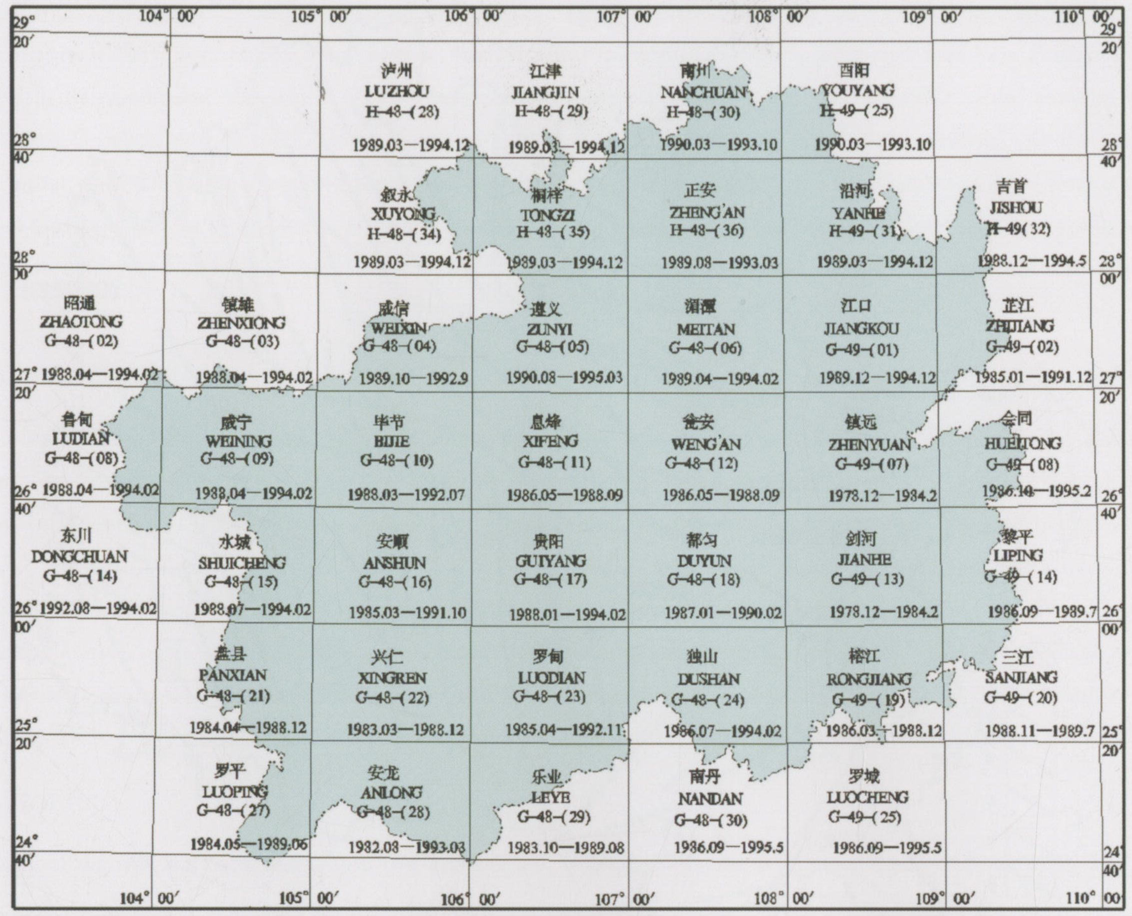


Fig. 6 Distribution of 1∶200 000 map sheets in Guizhou

Time of sampling is marked on each sheet.

They are used for monitoring the analytical bias between Guizhou and other laboratories in China.

1.2 Preparation of secondary reference (GRD) samples

10 secondary reference samples (GRD) were collected (see Fig. 7 for sampling locations) and numbered Gui GRD31—GRD40.

The 10 samples were taken from strata in the Panchi group, the Sinian System, the Cambrian System, the Emeishan Basalt, the Permian System, and the Triassic System (Table 1). Their far upper reaches may involve gold mines, antimony mines, lead-zinc mines, manganese mines, mercury mines, and tungsten-tin mines(see Table 1).

Table 1 Geology at the sampling sites in Guizhou(GRD)

No.	No. Sample	Location	Stratigraphy & lithology in upper rainage basin
1	GRD31	Qinglong	Permian sandstone & some clastic rock
2	GRD32	Sandu	Cambrian-Ordovician limestone & dolomitic limestone
3	GRD33	Hezhang	Carboniferous & Permian limestone & some clastic rock
4	GRD34	Ceheng	Triassic sandstone & shale, some Permian limestone
5	GRD35	Ceheng	Triassic sandstone & shale
6	GRD36	Jianhe	Pre-Sinian blastosandstone & slate
7	GRD37	Jinping	Pre-Sinian blastosandstone & slate
8	GRD38	Jiangkou	Pre-Sinian blastosandstone & magmatic rock
9	GRD39	Kaiyang	Sinian and Cambrian dolomitic limestone & limestone
10	GRD40	Zunyi	Permian and Triassic limestone & dolomitic limestone

The samples were mainly taken from silty sand, fine sand, and silt in the 2nd and 3rd order streams near weak

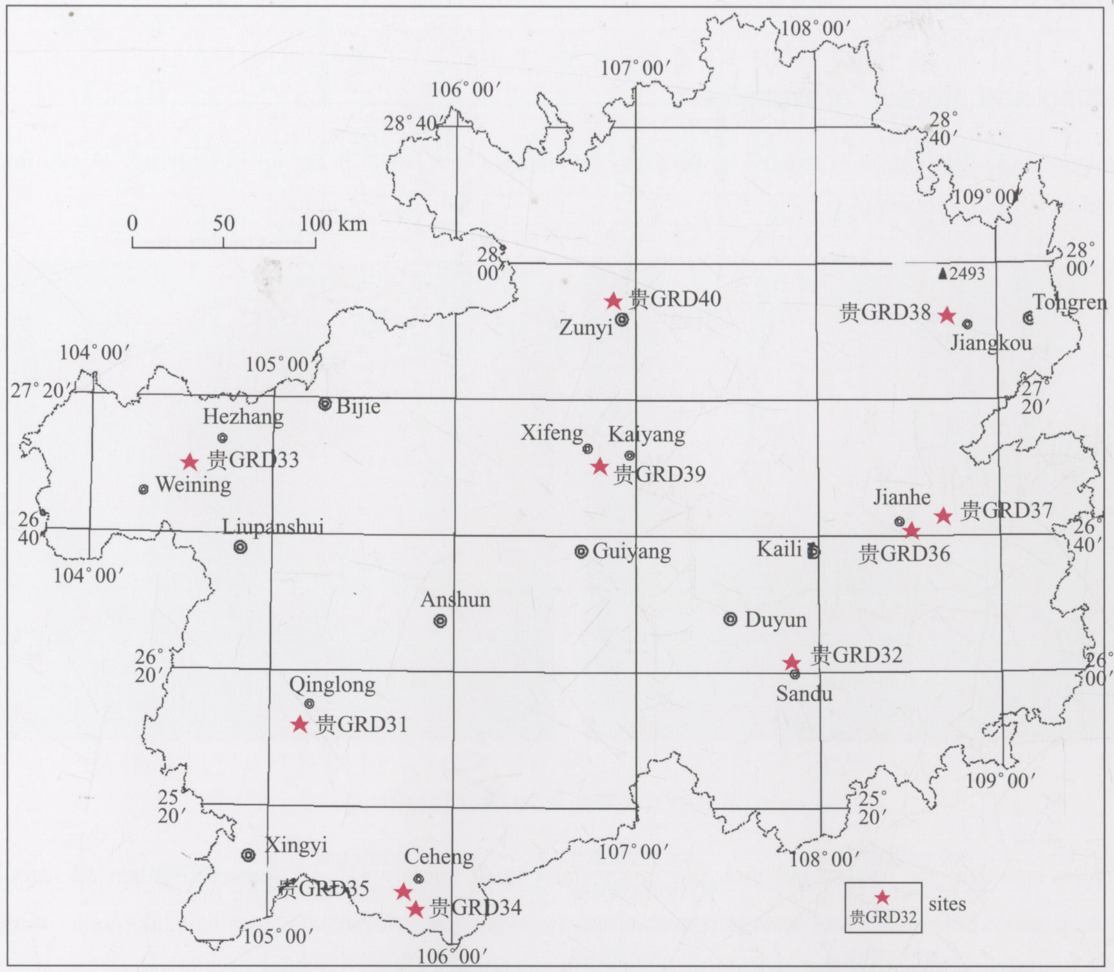


Fig. 7 Sampling sites of secondary reference samples of Guizhou (GRD)

mineralized points and weak anomalous regions. Each of them is greater than 100kg in weight.

Samples were dried by sunlight and then crushed with wood hammers. After 60-mesh sieving, they were all sent to the Analytical Data Quality Monitoring Station in the Institute of Geophysical and Geochemical Exploration in Langfang, Hebei Province, where they were pulverized by a large high-aluminum porcelain ball mill and directly ground to 200-mesh. Estimation of the homogeneity of samples were made following the instruction by Xie[12].

In order to determine the recommended values for Guizhou GRD samples, the processed samples were sent to laboratories in Sichuan, Yunnan, Guizhou and Hubei where the contents of 39 elements were analyzed. The laboratories adopted basically the same analytical methods to perform 3—6 repeated measurements of the samples. By statistic calculation, the recommended values for the Guizhou GRD samples were obtained (Table 2).

1.3 Orientation study on sampling

In the hilly regions with clastic rocks, drainage patterns are well developed. The RGNR sampling protocol for mountainous and hilly regions will be followed. The karst regions can be divided into karst mountains karst hills and karst plains. Pilot study on sampling in different geomorphic settings were performed including study on optimum sampling density, sampling medium and sample fractions, suitable for the mapping project in Guizhou [5].

2. Samplings

In order to have the samples to distribute more evenly in space, the 1 : 50 000 topographic maps were used as working map. On each map 1km^2 cells were plotted as sampling cell. Four sampling cells constituent an analytical cell[2]. One or two samples at the mouth of 1st order stream or in 2nd order stream were collected in each sampling cell (Fig. 8). All the samples will be mixed with equal weight to make a composite sample for analysis.

Table 2 Recommended element values in GRD samples

No.		GRD-31	GRD-32	GRD-33	GRD-34	GRD-35	GRD-36	GRD-37	GRD-38	GRD-39	GRD-40
1	Ag($\mu g \cdot g^{-1}$)	0.12	0.06	0.37	0.05	0.08	0.05	0.34	0.08	0.5	0.06
2	As($\mu g \cdot g^{-1}$)	143	88	118	12	2614	20	12	17	251	9
3	B($\mu g \cdot g^{-1}$)	24	104	24	70	110	104	109	45	70	87
4	Ba($\mu g \cdot g^{-1}$)	225	936	383	265	262	768	8280	171	1429	427
5	Be($\mu g \cdot g^{-1}$)	2.5	3.1	2.7	1.9	2	2.4	3.4	1.5	2.1	2.5
6	Bi($\mu g \cdot g^{-1}$)	0.2	0.5	1.2	0.3	0.4	0.3	0.4	0.3	0.3	0.5
7	Cd($\mu g \cdot g^{-1}$)	1	0.2	2.1	0.2	0.3	0.2	0.5	0.3	1.2	0.6
8	Co($\mu g \cdot g^{-1}$)	38	22	50	13	18	13	14	10	23	20
9	Cr($\mu g \cdot g^{-1}$)	105	97	133	51	55	66	148	54	56	116
10	Cu($\mu g \cdot g^{-1}$)	93	36	267	23	30	24	46	13	29	34
11	F($\mu g \cdot g^{-1}$)	483	1373	446	414	623	518	862	500	1075	803
12	Hg($\mu g \cdot g^{-1}$)	0.17	0.45	0.35	0.04	2.1	0.16	0.28	0.44	81	0.4
13	La($\mu g \cdot g^{-1}$)	35	35	48	27	31	36	48	31	41	41
14	Li($\mu g \cdot g^{-1}$)	27	45	26	25	46	52	45	46	35	41
15	Mn($\mu g \cdot g^{-1}$)	1628	665	2475	597	769	893	875	535	1687	1600
16	Mo($\mu g \cdot g^{-1}$)	2.8	1.2	2.5	0.5	0.7	1.1	11	2.3	7.8	1.5
17	Nb($\mu g \cdot g^{-1}$)	26	16	40	13	14	19	24	11	12	30
18	Ni($\mu g \cdot g^{-1}$)	33	40	69	24	27	26	42	19	64	40
19	P($\mu g \cdot g^{-1}$)	1712	457	1846	368	544	444	798	277	3515	699
20	Pb($\mu g \cdot g^{-1}$)	14	35	677	22	21	22	28	32	226	24
21	Rb($\mu g \cdot g^{-1}$)	19	138	59	82	92	111	143	39	61	141
22	Sb($\mu g \cdot g^{-1}$)	134	26.8	29.2	1.2	42.9	2.9	2.4	2.6	28.1	1.7
23	Sn($\mu g \cdot g^{-1}$)	3	3.5	3.9	2.4	2.6	3	4.2	2.2	2.3	3.2
24	Sr($\mu g \cdot g^{-1}$)	95	68	85	57	137	56	115	69	197	122
25	Th($\mu g \cdot g^{-1}$)	7	17	2	17	13	20	18	12	7	20
26	Ti($\mu g \cdot g^{-1}$)	13600	4000	24600	3400	3800	4800	4400	3000	2900	6800
27	U($\mu g \cdot g^{-1}$)	2.2	2.5	3.8	2.2	2.5	1.5	10.9	2.2	6	3
28	V($\mu g \cdot g^{-1}$)	249	103	414	81	104	95	410	83	87	197
29	W($\mu g \cdot g^{-1}$)	5.1	1.9	1.7	1.4	2.1	1.3	1.9	1.1	1.2	1.4
30	Y($\mu g \cdot g^{-1}$)	30	16	35	19	23	37	30	15	22	30
31	Zn($\mu g \cdot g^{-1}$)	121	111	2303	72	81	104	109	65	306	88
32	Zr($\mu g \cdot g^{-1}$)	191	116	374	245	201	282	175	141	163	307
33	SiO_2(%)	65.66	56.78	43.93	76.41	72.33	64.18	59.83	37.07	69.28	56.52
34	Al_2O_3(%)	9.03	15.04	15.36	9.78	11.51	16.38	15.44	6.67	8.72	16.11
35	Fe_2O_3(%)	13.43	8.62	17.91	4.56	5.66	5.85	6.47	3.37	5.56	8.25
36	K_2O(%)	0.6	3.55	0.93	1.76	2.01	2.95	3.29	0.63	1.69	3.52
37	Na_2O(%)	0.11	0.3	0.2	0.43	0.45	0.86	0.37	0.14	0.21	0.4
38	CaO(%)	0.79	2.97	1.52	0.34	0.56	0.43	0.8	17.17	2.55	1.8
39	MgO(%)	0.77	2.47	1.89	0.96	0.69	0.97	1.85	7.55	1.75	1.45

Stream sediment samples were collected in karst mountain and clastic rock hilly regions where drainage patterns are well developed. It can also be used in karst hills & valleys regions where drainage patterns of constant or temporary water flow exists. For karst mountain and karst hill regions with poorly developed drainage pattern or for karst plains, pond sediment or soil samples in the center of depressions were collected. The sampling density is the same as the collecting of stream sediment samples: One to two samples in each 1 km^2 sampling cells. The samples were sieved through a 60

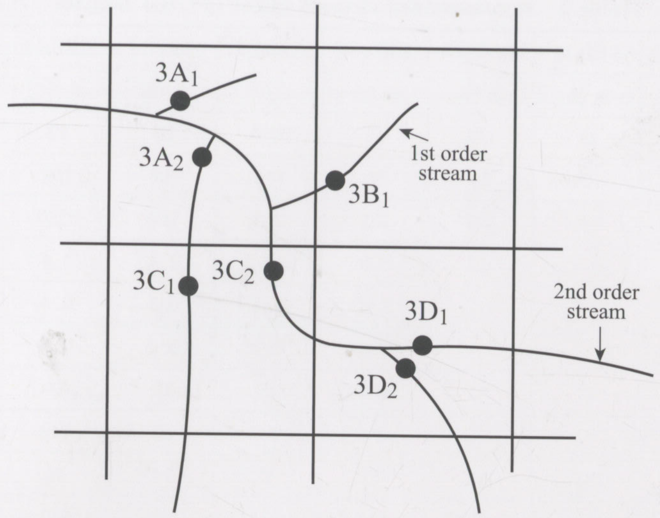


Fig 8 Example of coding for samples and standards in a map sheet for analysis

mesh, steel fibre sieve. All the samples in an analytical cell were composited together to send to laboratory for analysis. Within each 1 : 50 000 map sheet, two analytical cells were selected at random for duplicate sampling and duplicate analysis. The Luofan map sheet is taken as example to show the sampling layout (Fig. 9).

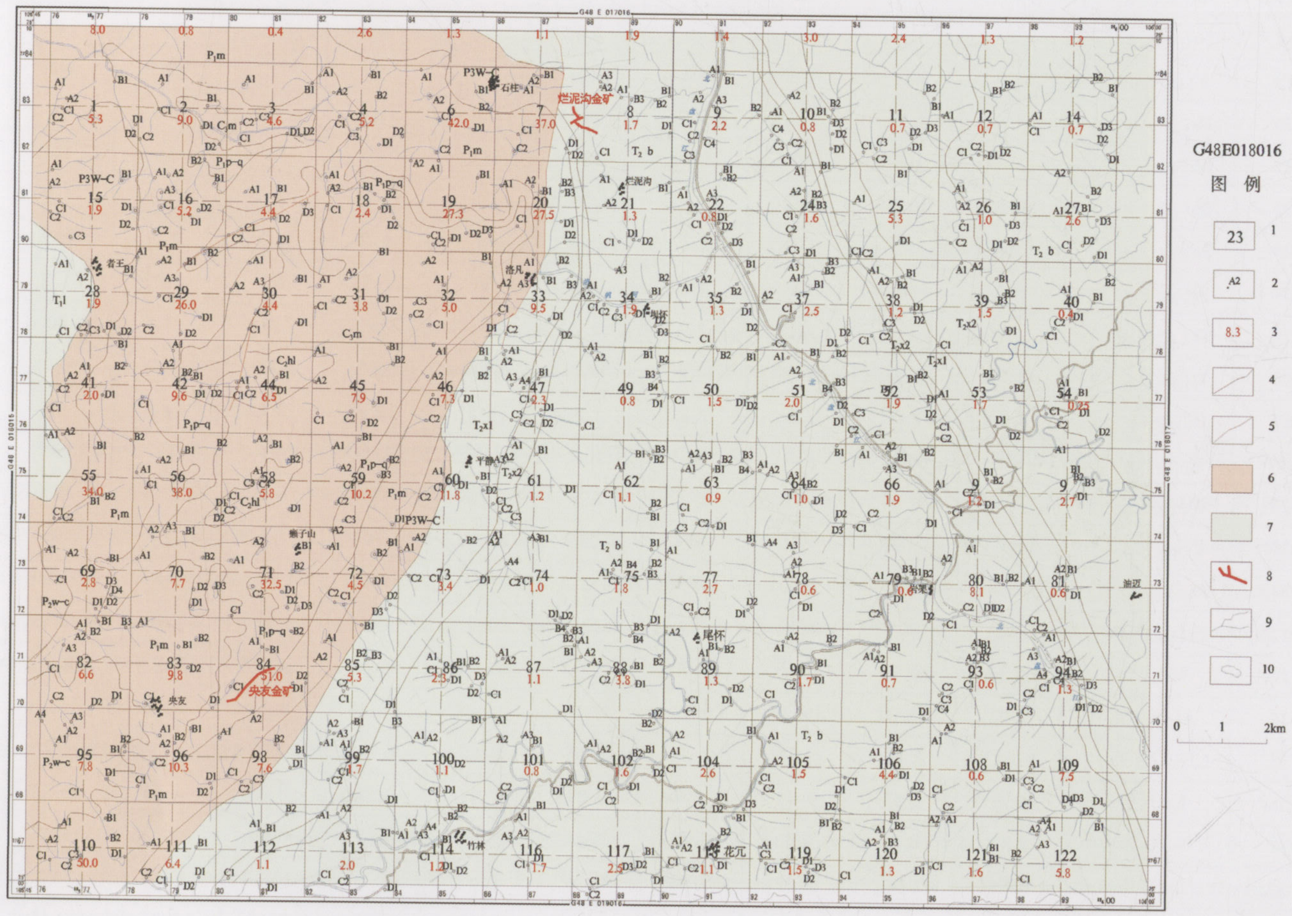


Fig. 9 Sampling layout in 1 : 50000 Luofan map sheet
1—Number of bigger sample; 2—Number of smaller sample; 3—Au results in bigger sample; 4—Geologic line; 5—Fault line; 6—Karst area; 7—Clastic rock area; 8—Gold deposit; 9—Water current; 10—Karst marsh land

* Classification of stream orders is following the system by Strahler[14].

V. Analysis of samples

1. Processing and storage of samples

Sample storehouse for long-term storage of samples: the sample storehouse is set up in Guiyang. A two floor buildings was constructed to store samples (Fig. 10).

Fig. 10 Sample bank in Guizhou Province

Samples are stored in PE bottles and then put in specially-made sample cabinet drawers. When all samples for a 1 : 500 000 map sheet have been sent into the storehouse, the sample storehouse manager will take same weight of all samples in each analytical cell to make composite samples (each weight 120g) for analysis.

2. Sample number coding

In each batch of samples (composite samples from one 1 : 50 000 map sheet), 2 primary standard (GSD) samples, 4 secondary reference samples, 2 duplicate samples will be inserted. The 2 duplicate samples will each analyzed two times. All these samples will be put into the batch for analysis with code number confidentially. The following is an example of sample number coding for Luofan map sheet samples sending for analysis [Fig. 11].

3. Multi-element analysis scheme

According to the RGNR Protocol, 39 elements should be analyzed. There are: Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cu, F, Hg, La, Li, Mn, Mo, Nb, Ni, P, Pb, Sb, Sn, Sr, Th, Ti, U, V, W, Y, Zn, Zr, SiO_2, Al_2O_3, Fe_2O_3, K_2O, Na_2O, CaO, MgO and Rb were also analyzed in addition.

Most of (85%) the sample analysis was undertaken by analytical laboratory in the Guizhou Bureau of Geology and Mineral Resources, Hubei, Guangxi and Guangdong; Besides, analytical laboratories in the Second Shanxi Geophysical Exploration party, Geophysical and Geochemical Exploration Group of Guizhou, Regional Geological Survey Group of Guizhou also participated in the analysis of some samples. The analysis of samples began in 1980 and ended in 1994, for a duration of 14 years (sampling were done in 1978—1992). Though the data quality monitoring procedure used had greatly reduced the various kind of analytical bias, yet the between-lab bias of Au, Ag, Be etc. are still significant between some map sheets. ❶

Table 3 lists the 39 element analytical scheme used, which is in accordance to the existing equipment and technical conditions in those past years.

❶ Analysis done in Guizhou were performed in an early date. Such kind of bias does not exist at present.

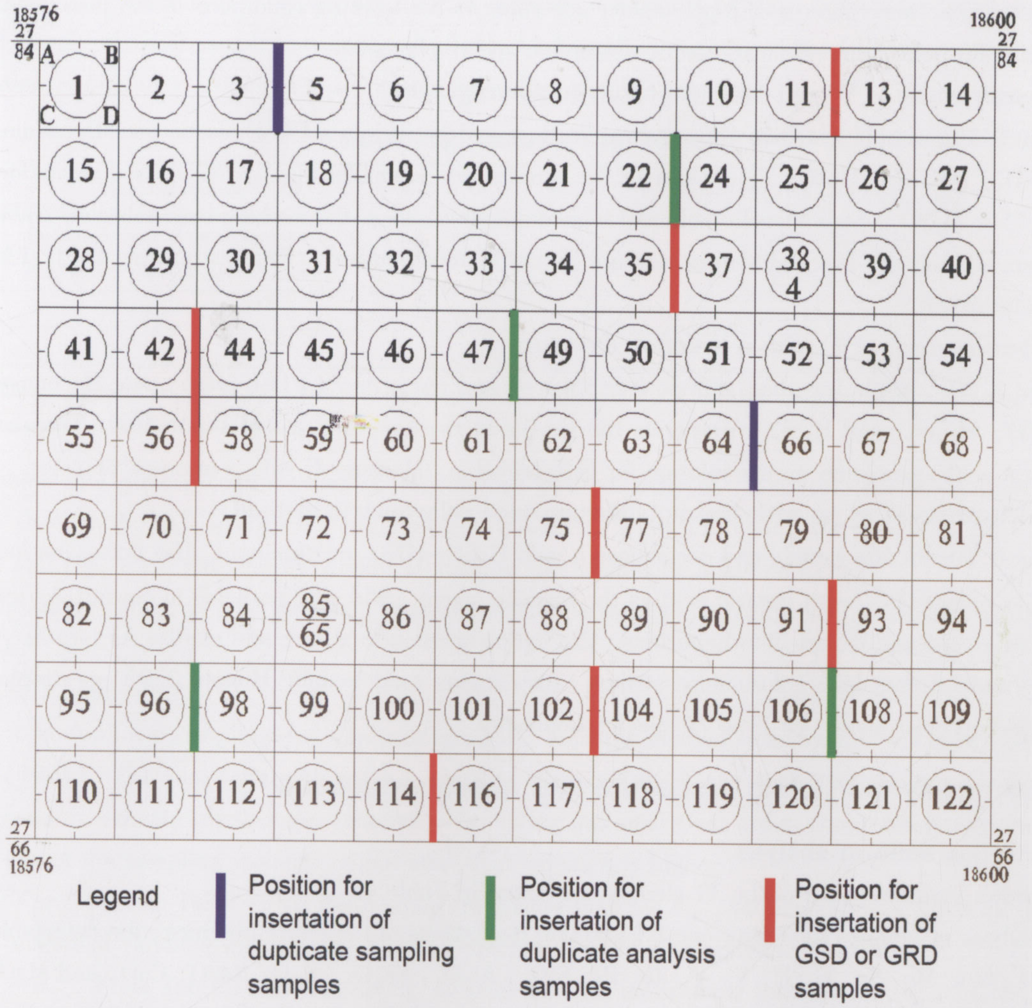
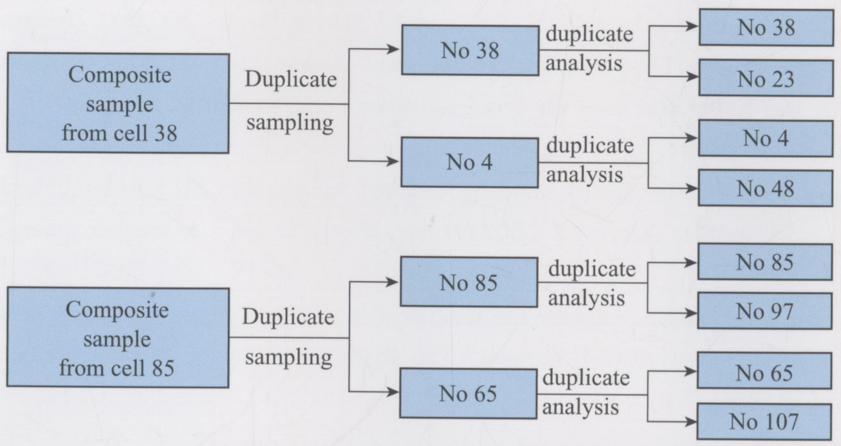


Fig. 11 Sample number coding, Luofan map sheet (G-48-104-D)



3.1 Measurement of As, Ba, Co, Cr, Cu, La, Mn, Nb, Ni, P, Pb, Rb, Sr, Th, Ti, V, Y, Zn, Zr, Na_2O, K_2O, MgO, CaO, Fe_2O_3, Al_2O_3, and SiO_2 with X-ray fluorescence spectrometry

Weigh out 4.00g sample powder that has already been oven-dried at 105℃ and has a grain fineness less than 200-mesh. Fill the sample in low pressure polyethylene (or aluminum) cup and put it under 35t pressure to form a round disc which is 32mm in diameter. Measure the sample with a wavelength-dispersion X-ray fluorescence spectroscope. Standard curves using primary standard reference sample are constructed. Correct the matrix effects of major and minor elements with the experience coefficient method. Use Compton scattered rays of the target line for the internal standard correction of the matrix effects of microelements. Use the regression method to calculate the matrix correction coefficient and spectral line overlap correction coefficient.

Table 3 Analytical scheme for 39 elements

No.	Analysis method	Number of items	Elements or oxides analyzed
1	X-ray fluorescence spectrometry (XRF)	26	SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, Na_2O, As, Ba, Co, Cr, Cu, La, Mn, Nb, Ni, P, Pb, Rb, Sr, Ti, Th, V, Y, Zn, Zr
2	Atomic fluorescence spectrometry (AF)	2	As, Bi, Sb
3	Emission spectrometry (ES)	4	B, Be, Sn, Li
4	Polarography (POL)	2	W, Mo
5	Ion selective electrode (ISE)	1	F
6	Atomic absorption method (AAS)	2	Ag, Cd
7	Chemical-spectral analysis (CES)	1	Au
8	Cold vapor Atomic Fluorescence Spectrometry Mercury detector (CVAF)	1	Hg
	Laser fluorescence (LF)	1	U

3.2 Measurement of Be, Co, Cr, Cu, Li, Mn, Ni, P, Ti, V, Zn, Al_2O_3, Fe_2O_3, K_2O, Na_2O, CaO, and MgO with plasma optical emission spectrometry

Weigh out 0.25—0.50g of sample and decompose it with HF, HNO_3, $HClO_4$, and aqua regia, and then measure the 17 elements or oxides in the sample solution with plasma optical emission spectrometry.

3.3 Measurement of As, Sb, and Bi with hydride-atomic fluorescence spectrometry

Use 1 + 1 aqua regia to dissolve and decompose the sample, and add 1% $KMnO_4$ solution for oxidation. Use 1% oxalic acid solution to dilute it. And use thiourea-ascorbic acid for reduction. Then measure As and Sb with hydride-atomic fluorescence spectrometry by using KBH_4 as the reducing agent and an XGY-1011A atomic fluorescence spectrometer, which is equipped with a special-purpose hollow cathode lamp as the excitation light source and an automatic low-temperature argon-hydrogen flame ignition device. Bi is measured without pre-reduction.

3.4 Measurement of Hg with cold vapor-atomic fluorescence spectrometry

Use aqua regia to dissolve and decompose the sample, and then treat the sample with 1% $KMnO_4$ and 1% oxalic acid solution. Use an Hg special-purpose hollow cathode lamp or high-intensity hollow cathode lamp and $SnCl_2$ as the reducing agent to reduce Hg^{2+} in the solution into Hg vapor which is then led through a gas duct into a quartz atomizer preheated to 200℃ for cold vapor-atomic fluorescence spectrometry measurement. The solution fabricated with this method can also be used for the analysis of As and Sb, and after being rested for 48h, for the measurement of Bi. It can realize sample decomposition in one step and the measurement of As, Sb, Bi, and Hg at the same time.

3.5 Measurement of Au with plastic foam absorption enrichment-graphite furnace atomic absorption spectrometry

Scorch the sample at 650℃ and then decompose it with 1 + 1 aqua regia. Use EU plastic foam to absorb Au in the medium of 5%—20% aqua regia. Use 1.2% thiourea solution for disengagement. Then use a special-purpose long-life graphite tube, maximum-capacity temperature rise, and peak height measurement and Zeeman background correction technology and ascorbic acid as the matrix modifier to measure ultra trace Au with graphite furnace atomic absorption spectrometry. Use flame atomic absorption spectrometry to measure constant Au.

3.6 Measurement of Ag, B, Sn, Mo, Pb, Be, and Li with emission spectrometry

Use $K_2S_2O_7$, NaF, Al_2O_3 and carbon powder as the buffer agent. Use an AC arc light source and two sample-loaded electrodes to obtain two overlapping spectrographs. Use different developing times for shortwave phase plate and long-wave phase plate. And use Ge as the internal standard element for the emission spectrometry measurement of Ag, B, Sn, Mo, Pb, Be, and Li in geochemical prospecting samples.

3.7 Measurement of F with the ion selective electrode method

Melt the sample with NaOH at 700℃, extract it with water. Neutralize the solution with H_2SO_4, and add ion regulator. Directly use a fluorine selective electrode to measure the potential on an ionic-activity meter, and thus calculate the content of F in the sample.

Table 4 Detection limits and report rates of the sample analysis methods for 1 ∶ 200 000 regional geochemical exploration of Guizhou

No.	Element/oxide	Analysis method	Required detection limit	Actual detection limit of analysis	Report rate (%)	Remarks
1	Ag	AAS, ES	0.01 ~ 0.02	0.02	90 ~ 100	1. Analysis methods: AAS-atomic absorption; AF-atomic fluorescence; CES-chemical spectrometry; CHG-Hg detector; COL- colorimetry; ES-emission spectrometry; ICP- plasma quantometer; ISE-ion selective electrode; LF-laser fluorescence method; POL-polarography; XRF-X-ray fluorescence spectrometry 2. The analysis methods and actual detection limits of analysis are ranked according to the primary; secondary, and individual analysis methods adopted for forty-one 1 ∶ 200 000 map sheets of the entire province 3. Units for contents: % for oxides and μg/g for other elements 4. Multiple values in a detection limit of analysis are detection limits in different years or different laboratories
2	As	XRF, AF, COL	1	1, 2, 0.5	90 ~ 100	
3	Au	CES	0.0003	0.001, 0.0005, 0.0003	80 ~ 100*	
4	B	ES	5 ~ 10	5	90 ~ 100	
5	Ba	XRF, ICP, ES	50	15	100	
6	Be	ES	0.5	0.5, 0.2	100	
7	Bi	AF	0.1	0.1, 0.05	100	
8	Cd	AAS	0.1	0.1, 0.04	90 ~ 100	
9	Co	XRF, ICP, ES	1	2.3, 1	90 ~ 100	
10	Cr	XRF	15	15, 4.8	90 ~ 100	
11	Cu	XRF, ICP, ES	1	4.5, 1	90 ~ 100	
12	F	ISE, POL	100	100, 50	100	
13	Hg	CHG, AF, AAS	0.01	0.005, 0.01	80 ~ 100	
14	La	XRF, ICP, ES	30	30, 10	80 ~ 100	
15	Li	ES, AAS	5	5, 1	100	
16	Mn	XRF, ICP, ES	30	30, 2	100	
17	Mo	POL, ISE	0.5	0.1, 0.5, 0.15	100	
18	Nb	XRF	5	10, 5, 0.5	90 ~ 100	
19	Ni	XRF, ICP, ES	1 ~ 10	10, 3.2, 2	90 ~ 100	
20	P	XRF	100	10, 50, 30	90 ~ 100	
21	Pb	XRF, AAF	1 ~ 10	10, 5, 2	90 ~ 100	
22	Sb	AF	0.2	0.2, 0.1, 0.01	90 ~ 100	
23	Sn	ES	1 ~ 3	1.5, 1.2	90 ~ 100	
24	Sr	XRF, ICP	5 ~ 50	10, 2, 1	100	
25	Th	XRF	4	2.4, 1.8	90 ~ 100	
26	Ti	XRF	100	44	100	
27	U	LF, POL	0.2 ~ 1	0.5, 0.2, 0.1	100	
28	V	XRF, ICP, LF	20	4, 1.1	100	
29	W	POL, ISE	0.5	0.5	90 ~ 100	
30	Y	XRF	5 ~ 10	10, 2, 0.8, 0.4	100	
31	Zn	XRF, ICP, AAS, ES	10	10, 3.9	100	
32	Zr	XRF	10	10, 4.8, 3.9	100	
33	SiO_2	XRF	0.10	0.02	100	
34	Al_2O	XRF	0.05	0.02	100	
35	Fe_2O	XRF	0.05	0.01	100	
36	K_2O	XRF	0.05	0.02	100	
37	Na_2O	XRF	0.05	0.01	100	
38	CaO	XRF	0.05	0.01	100	
39	MgO	XRF	0.05	0.01	100	

3.8 Measurement of Ag and Cd with graphite-furnace atomic absorption spectrophotometry

Weigh out 0.10—1.00g of sample less than 180-mesh in fineness and decompose it with HF-H_2SO_4-HNO_3 or HF-HNO_3-$HClO_4$. In 2% sulphuric acid medium or HCl-diammonium phosphate medium, measure Ag and Cd with a graphite-furnace atomic absorption spectrophotometer according to the working conditions of the instrument, the instrument being 180—80 polarization Zeeman atomic absorption spectrophotometer.

3.9 Measurement of W and Mo with catalytic polarography

Weigh out 0.10g sample less than 180-mesh in fineness and put it into a PTEF plastic pot. Decompose the sample with HCl, HNO_3, HF, and $HClO_4$, and separate the interference elements through NaOH sedimentation. By experimentation, 1.65% H_2SO_4, benzoglycolic acid and cinchonine are used as the working base solution. Split the clear solution and direct add mixture base solution to measure W and Mo consecutively. The instruments are JP-1A and JP-2 oscillographic polarograph.

3.10 Measurement of U with a uranium detector

Weigh out 1.00g sample less than 180-mesh in fineness and put it into a PTEF plastic pot. Decompose the sample with HNO_3, HF, $HClO_4$, and H_2SO_4, evaporate the sample to dryness, and leach it with HCl. Then add aluminum-containing nitric acid-ammonium nitrate solution for defluoridation. Measure U with a uranium detector.

3.11 Measurement of As with the molybdenum-blue colorimetric method

Weigh out 0.10—0.50g sample and decompose it with H_2SO_4-HNO_3 mixture acid. Use potassium iodide and stannous chloride to reduce As^{5+} with tartaric acid as the masking agent. Add zinc particles to convert As into arsenic hydride which can escape and depart from impurities. Use iodine solution to absorb and oxidize As into As^{5+}, then measure it with the molybdenum-blue colorimetric method. Instruments used include Hitachi 220A spectrophotometer, EIKO-Ⅱ photoelectric colorimeter, or Type 72 spectrophotometer.

4. Analytical quality monitoring procedure and quality evaluation

4.1 Detection limits of analysis

The detection limits required of the 39 element are listed in Table 4.

In the analysis of samples from forty-one 1 ∶ 200 000 map sheets of the entire province, the detectable rates of Ba, Be, Bi, F, Li, Mn, Mo, Sr, Ti, U, V, Y, Zn, Zr, SiO_2, Al_2O_3, Fe_2O_3, K_2O, Na_2O, CaO, and MgO data were all 100%. The early (1980—1983) detectable rates of analysis data of Ag, As, B, Cd, Co, Cr, Cu, Nb, Ni, P, Pb, Sb, Sn, Th, and W were between 90% and 100%; and the early (1980—1983) report rates of analysis data of Hg, La were between 80% and 100%.

The detectable detectable rates of Au were 52.9% and 50.9% in the 1 ∶ 200 000 Zhenyuan and Weng'an map Sheets in early work and did not meet the standard requirements. Detectable rates of Au analysis data in all other map sheets are between 80% and 100% and meet the requirement on detectable rates.

4.2 Accuracy and Precision

For the monitoring of accuracy the primary standard reference sample set GSD 1-8 should be inserted into every 1 ∶ 100 000 map sheets (i.e. 2 samples in every 1 ∶ 50 000 map sheet) in order to monitor the systematic error occurred within this data set.

Average of $\Delta \lg C$ ($\overline{\Delta \lg C}$) is used to estimate the analytical bias. $\Delta \lg C$ is the derivation of the measured values of GSD samples from the certified values of GSD samples. The allowance values of $\overline{\Delta \lg C}$ for a qualified data set are listed on Table 4.

Table 5 Monitoring limits for GSD

Range of data	$\overline{\Delta \lg C}(GSD) = \frac{1}{4}\sum(\lg C_i - \lg C_s)$
Within 3 times of detection limit	≤ ±0.15
More than 3 times of detection limit	≤ ±0.12
1%—5%	≤ ±0.07
>5%	≤ ±0.05

Note: C_s is the certified value of GSD samples; C_i the measured value of GSD samples standard substance.

For the data set on the fourty one 1 ∶ 200 000 map sheets, only Ag, As, Hg, Ni and Pb show slight systematic errors.

The secondary reference GRD samples are used to estimate the results between batches or between map bias. In each batch of samples 4 GRD samples are inserted (Table 5) Fig. 12 is a quality control Chart showing the variation of $\Delta \lg C$ (derivation of measured values from recommended values of GRD samples).

Table 6 $\overline{\Delta \lg C}$ limits for GRD samples

Range of content	$\overline{\Delta \lg C}(\mathrm{GRD}) = \frac{1}{4}\sum(\lg C_i - \lg C_s)$
Within 3 times of detection limit	≤ ±0.20—0.25
More than 3 times of detection limit	≤ ±0.10—0.15
1%—5%	≤ ±0.1
>5%	≤ ±0.05

Note: C_s is the recommended value of SGRD sample; C_i is the measured value of the i GRD in the 4 GRD samples. $\overline{\Delta \lg C_i}$ is the average logarithmic difference between the measured value and the recommended values of the 4 GRD.

Fig. 12 shows the quality control chart of 48 batch of routine analysis. Samples were taken from 1 : 200 000 Jiangkou map sheet by N. 103 Geological Party, Guizhou Province. From the chart, the quality of Ag, Sb and Bi are good. For Cd and Hg, there are several batches of samples that should be analyzed again.

Due to the nugget effect in gold analysis, standard reference samples, specific for use in gold analysis were prepared by IGGE.

Analysis of Variances.

For data from duplicate sampling and duplicate analysis, a simple method of analysis of variance was developed by R. G. Gurrett (1973). The total variance (σ_D^2), sampling variance (σ_S^2) and analytical variance (σ_a^2) are calculated, F test is used to estimate whether the variation of sampling and analytical errors could deteriorate the geochemical variation and one of the sampling variance or the analytical variance is higher.

$F_1 = \sigma_D^2 / \sigma_{SA}^2$. From Table 7, all these ralios are greater than the $F_{0.05}$ value on 95% confidence level, then the sampling and analytical variance will have no or little effect on the actual geochemical variation.

$F_2 = \sigma_s^2 / \sigma_a^2$. From Table 7, for the Zheng'an map sheet as an example the ratios of Ag, As, B, Be, Bi, Cr, Hg, Li, Pb, Sb, Th, W and N_2O are slightly less than the $F_{0.05}$ value at 95% confidence level. This shows that the analytical variances of these elements are a little higher than the sampling variances at that time. For other elements, the sampling variances are a little higher than analytical variance.

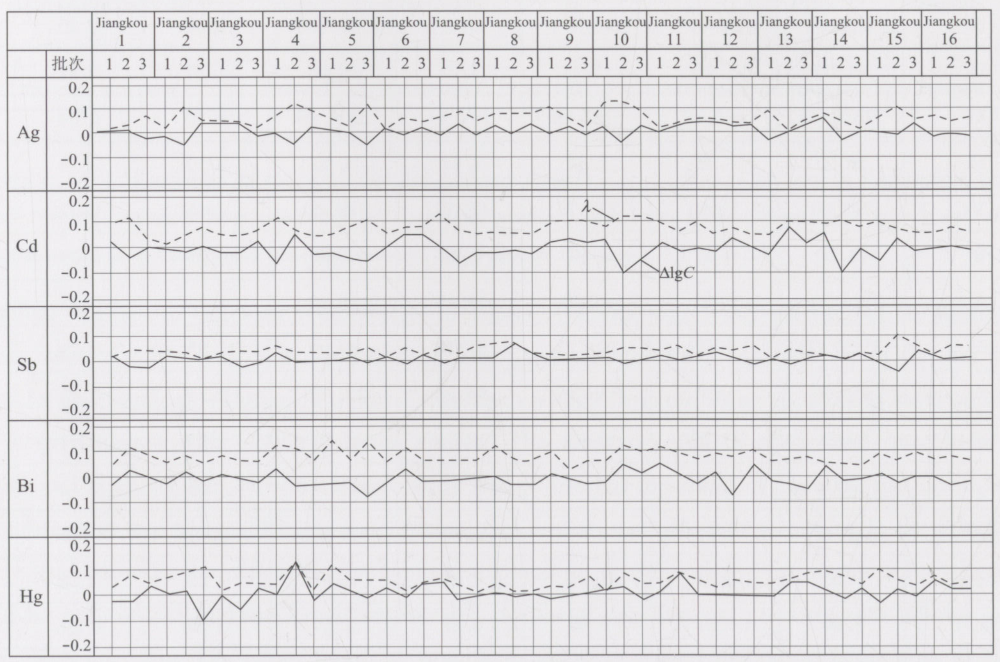


Fig. 12 Quality control chart of routine batch analysis

1 : 200 000 Jiangkou map sheet consists of sixteen 1 : 50 000 Jiangkou map sheet, secondary reference GRD samples are inserted with 3 batches, totally 48. The real line is $\Delta \lg C$, imaginary line is $\sqrt{\frac{1}{4}\sum(\lg C_i - \Delta \lg C)^2}$

Table 7 Results of F value inspection on repeated samples in 1 : 200 000 Zheng'an Yanhe, Zunyi, Weining, and Meitan Sheets

No. 1	Element /oxide	Zheng'an Sheet		Yanhe Sheet		Zunyi Sheet		Weining Sheet		Meitan Sheet	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
	Ag	4.12	0.85	18.36	1.1	5.32	0.68	10.92	1.14	2.3	0.93
2	As	41.02	1.39	46.14	1.65	147.6	1.03	63.41	1.24	179.4	2.9
3	B	107.5	1.22	32.87	1.12	68.7	1.43	68.00	0.78	41.6	1.01
4	Ba	68.67	1.52	68.31	1.39	15.12	4.06	91.07	1.21	41.6	2.05
5	Be	6.76	1.33	15.12	1.16	16.17	0.93	14.01	0.79	10.7	1.15
6	Bi	9.21	0.89	20.22	0.82	9.83	1.04	6.05	0.82	6.48	1.66
7	Cd	4.57	8.98	75.38	0.16	41.78	2.74	25.41	1.6	48.85	0.74
8	Co	52.62	1.91	43.9	1.24	140.4	1.43	157.1	1.06	99.92	1.78
9	Cr	127.4	1.09	21.01	0.25	244.4	1.02	248.1	0.66	131.1	1.19
10	Cu	531.8	2.05	25.25	2.05	424.6	1.11	98.96	2.51	399.4	1.79
11	F	16.08	1.46	20.14	1.63	49.3	1.06	62.22	1.15	44.65	0.68
12	Hg	46.27	0.95	262.1	4.87	13.16	1.15	51.00	1.16	96.4	0.72
13	La	28.56	2.74	20.88	1.34	100.7	1.13	49.26	1.34	64.7	1.67
14	Li	61.12	0.57	26.88	7.25	141.3	0.99	3.53	1.01	78.8	2.42
15	Mn	15.36	203.3	74.53	3.23	14.33	74.2	51.56	1.16	119.6	10.14
16	Mo	32.6	2.24	11.41	9.52	41.59	0.98	23.68	1.34	42.48	0.81
17	Nb	99.58	1.85	15.67	9.96	305.7	1.76	339.9	1.98	245.4	0.94
18	Ni	33.78	2.13	23.65	1.35	125	1.19	53.08	1.16	166.3	0.76
19	P	54.56	4.37	70.98	0.89	67.63	2.58	71.18	1.19	130.8	1.46
20	Pb	113.8	0.93	719.8	0.98	25.53	2.34	36.81	51.87	22.1	0.89
21	Rb	55.51	12.19	92.06	1.88	41.87	1.1	134.7	2.48	293.2	1.91
22	Sb	18.19	0.7	36	5.25	10.04	1.54	60.83	0.74	26.47	0.64
23	Sn	4.13	1.53	17.52	1.08	7.06	1.79	11.83	1.41	6.64	1.16
24	Sr	156.3	10.6	51.34	3.58	348.6	2.95	186.8	7.08	51.76	8.77
25	Th	19.42	0.61	14.42	1.09	10.23	0.69	13.47	1.43	17.23	0.84
26	Ti	279.6	13.55	45.49	0.84	1914	1.57	311.2	1.28	2578.4	2.35
27	U	24.05	1.74	9.74	1.27	18.6	0.95	23.4	1.12	11.47	1.89
28	V	122.2	1.49	33.85	1.16	240.1	0.98	150.9	1.27	36.89	0.72
29	W	14.95	0.86	34.82	1.34	12.5	1.11	50.00	0.89	33.77	0.63
30	Y	37.81	3.65	24.89	2.49	62.69	1.11	30.34	2.26	70.73	1.19
31	Zn	18.52	1.78	25.07	49.35	49.08	2.5	75.34	10.15	174.0	1.42
32	Zr	137.8	10.32	31.08	3.98	147.2	5.49	27.98	1.68	139.0	2.89
33	SiO_2	28.48	9.43	77.9	1.23	27.52	1.09	74.88	1.93	226.82	1.55
34	Al_2O_3	39.06	8.97	36.62	1.58	112.7	4.42	45.42	1.7	49.68	2.02
35	Fe_2O_3	104.5	23.24	19.2	4.47	225.3	1.32	186.9	1.43	191.9	1.44
36	K_2O	70.79	6.49	12.74	1	214.3	1.23	245.1	1.33	71.11	1.63
37	Na_2O	13.25	0.99	18.54	1.28	63.38	0.94	16.61	1.47	10.94	1.26
38	CaO	35.38	74.04	19.82	30.11	210.6	3.48	85.41	1.13	263.6	3.33
39	MgO	35.15	8.15	30.33	1.58	95.64	3.6	113.1	1.23	150.95	1.18
$F_{0.05}$		1.5	1.44	1.69	1.51	1.67	1.53	1.67	1.53	1.61	1.48

Note: This table is based on the geochemical map instructions (stream sediment measurement) of Zheng'an Yanhe, Zunyi, Weining, and Meitan Sheets [M] (Dec. 1993, not published) made by No. 109 Team of Institute of Geophysical and Geochemical Survey of Guizhou Bureau of Geology and Mineral Resources.