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Geochemical characteristics and evolution of REE in the Early Precambrian sediments : evidence from the southern margin of the North China Craton

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The REE characteristics of both the chemical and the clastic sediments from six early Precambrian terrains at the southern margin of the North China craton show that the sedimentary Eu-depletion started from about 2300 Ma and the values of ΣREE of the sediments less than 2300 Ma are higher than those of the sediments more than 2300 Ma. These phenomena can be logically ascribed to considering the changes in surficial environment and interpreted by using the new HSAB (hard and soft acids and bases) theory. We argue that the sediments deposited in anoxic environment before 2300 Ma are characterized by positive Eu-anomaly, low ΣREE and occasionally high La_N/Yb_N ; whereas the sediments in oxidic condition after 2300 Ma show Eu-depletion, high ΣREE and low La_N/Yb_N . Possibly, the surficial environment (including atmosphere) turned to be oxidic at about 2300 Ma. Hence, the REE can be used to indicate the nature of the environment.

Introduction

At the beginning of the Proterozoic, significant changes took place in many respects of the earth (Condie, 1981, 1982, 1993; Kroner, 1981; Frakes, 1979; Schopf, 1977; Eriksson and Truswell, 1978; Hu, 1988; Sun, 1984; Chen, 1989, 1990; Chen et al., 1991a, 1994, 1996; Taylor and McLennan, 1985; McLennan and Taylor, 1991). Taylor and McLennan (1985) advanced that the Archean sediments showed clear negative Eu-anomaly. Eu-depletion of the post-Archean sediments is attributed to the extensive development of K-granite at the end of the Archean. By Taylor's model, the REE characteristics of the sediments are controlled by their provenance rather than the process of weathering-deposition-diagenesis-metamorphism or the sedimentary environments. Through the study of the southern margin of the North China craton, we find that, besides the provenance of sediments, the sedimentary environment is a chief factor affecting the characteristics of REE in the sediments. Based on the HSAB (hard and soft acids and bases) theory (Dai, 1987) and the consideration of the changes in sedimentary environment, this paper gives an interpretation of the geochemical evolution of REE in the sediments from the southern margin of the North China craton and establishes a new model to explain the differences in REE between the Archean and the post-Archean sediments.

Geology and stratigraphy

The southern margin of the North China craton comprises the Huaxiong block and the Songji block (Figure 1). The Huaxiong block is made up of the Xiaoshan terrain and the Taihua united terrain which includes the Lushan, Wuyang, Xiong'ershan and Xiaoqinling Early Precambrian terrains. The Songshan and Jishan Early Precambrian terrains are exposed in the Songji block (Figure 1). The stratigraphy and tectonic evolution of the some terrains are generalized (Table 1, Figure 2) on the basis of a comprehensive work including field investigation and study of petrology, geochemistry, geochronology, stratigraphy, etc. (Chen, 1987; Chen et al., 1988, 1989, 1991b; Chen and Fu, 1992). These terrains were developed during the period from 3000 Ma to 2100 Ma. The Archean-Proterozoic transition in the area in question occurred 2300 Ma ago.

Figure 1 Distribution of early Precambrian terrains at the southern margin of the North China craton

All the rocks formed before 2300 Ma are similar to the typical Archean rock associations described by Condie (1982) such as the greenstone belts and the TTG (tonalite-trondhjemite-granodiorite) suites. As discontinuous inclusions (relicts) in the Shipaihe complex

Table 1 Stratigraphy and tectonic evolution of some blocks and terrains

Geologic time	Huaxing block		Songji block
	Taihua united terrain	Xiaoshan Terrain	
1400–1850 Ma	cover: Xiong'er Gp. volcanics	cover: Xiong'er Gp. volcanics	uplifting, erosion
Zhongyue movement	formation of the southern margin of the North China craton amalgamation of the Huaxiong block with Songji block		
1850–2150 Ma	Tietonggou Gp. intramontane molasses	Tietonggou Gp. intramontane molasses	Songshan Gp. cratonic sediments
Songyang Movement	amalgamation with the Xiaoshan terrain	amalgamation with the Taihua united terrain	close of the Angou-Xiaoshan rift
2150–2300 Ma	Shuidigou Gp. khondalite series	Xiaoshan Gp. bimodal volcanics	Angou Gp. bimodal volcanics
Guojiayao Movement	catastrophe in surficial environment; cratonization of Huaxiong block	diverge from Songji; metamorphism and migmatization	rifting; metamorphism and pegmatite intrusion
2300–2550 Ma	Dangzehe Gp. secondary greenstones	Tianyemiao Complex migmatite-granitoids	Junzhao Gp. secondary greenstones
Shipaihe Movement	cratonization	?	cratonization and accretion of Songji sialic nucleus
2550–3000 Ma	Beizi Gp. greenstones developed on oceanic setting	?	Shipaihe Complex: migmatites, TTGs and high grade metamorphic rocks
Qingyanggou Movement	rifting of primary simatic crust, coming into being of a proto ocean	?	Intrusion of TTGs such as Shipaihe and Yuyao masses
>3000 Ma	?	?	Qingyanggou greenstones

Table 3 REE behavior in waters and in sediments and their relationship with the nature of environment

Nature of environment	Oxidic environment	Reducing environment
fO_2	high	low
Eu^{3+}/Eu^{2+}	high	low
species of Eu	predominance of Eu^{3+}	predominance of Eu^{2+}
ligands (generally anions) for coordination	hard bases such as OH^- , CO_3^{2-} , SO_4^{2-} , and NO_3^-	soft bases such as HS^- , S^{2-} , SCN^- , $S_2O_3^{2-}$ and CO
sequence of REE to coordinate and precipitate	$HR^{3+} > LR^{3+} > Eu^{2+}$	$Eu^{2+} > LR^{3+} > HR^{3+}$
cations into complexes and precipitated	hard acids such as Eu^{3+} , R^{3+}	soft acids such as Eu^{2+}
cations tend to retain in water	soft acids such as Eu^{2+}	hard acids such as Eu^{3+} , R^{3+}
sedimentary REE feature	high ΣREE , low Eu/Eu^* and low La_N/Yb_N	low ΣREE , high Eu/Eu^* and high La_N/Yb_N

Table 2 Petrochemical and rare earth composition for the sediments from the southern margin of the North China craton

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Other	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	La _N /Yb _N	Eu/Eu*	ΣREE
1	68.46	0.44	15.72	2.85	0.88	0.04	1.03	3.67	4.24	0.97	0.08	1.42	35.91	60.40	7.30	21.21	3.00	1.22	1.69	0.30	0.90	0.19	0.46	0.08	0.38	0.05	54.75	1.52	133.09
2	74.36	0.04	13.53	0.18	0.49	0.01	0.30	2.52	3.93	3.30	0.02	1.33	4.70	5.10	0.87	2.11	0.38	0.47	0.29	0.07	0.25	0.04	0.11	0.02	0.09	0.01	30.26	4.20	14.51
3	70.28	0.70	11.49	2.99	3.70	0.05	1.12	0.82	2.09	5.43	0.15	0.54	9.14	24.19	3.88	16.47	4.04	1.10	4.09	0.74	4.47	0.89	2.51	0.39	2.29	0.32	2.31	0.83	74.52
4	57.04	0.53	14.07	2.19	3.70	0.05	5.48	3.73	1.37	1.67	0.10	9.89	14.71	35.22	4.03	12.18	2.54	0.77	2.18	0.41	2.15	0.43	1.24	0.19	1.15	0.16	7.41	0.99	77.36
5	56.80	0.35	7.17	1.29	3.25	0.10	10.12	12.75	0.86	2.04	0.10	4.66	18.55	37.16	5.54	20.74	4.68	0.82	4.12	0.75	4.25	0.81	2.38	0.36	2.28	0.30	4.71	0.56	102.74
6	8.66	0.45	2.28	0.49	0.98	0.03	2.29	46.11	0.46	0.40	0.16	37.95	16.10	32.80	4.01	12.79	2.51	0.54	1.97	0.34	1.53	0.30	0.73	0.12	0.54	0.07	17.27	0.72	74.35
7	52.60	0.45	22.08	1.39	1.85	0.10	5.03	3.38	4.24	3.39	0.10	5.00	19.32	42.41	6.01	22.78	5.07	0.85	4.57	0.78	4.33	0.87	2.54	0.39	2.49	0.36	4.50	0.53	112.77
8	66.10	0.25	19.01	0.67	0.55	0.03	0.71	0.56	10.96	0.20	0.03	0.58	7.26	48.74	3.94	11.11	3.84	0.41	4.50	1.00	6.88	1.35	4.06	0.62	4.07	0.49	1.03	0.30	98.27
9	52.32	0.55	14.37	6.37	0.43	0.08	9.30	6.31	4.68	0.59	0.10	3.96	40.29	68.20	8.53	26.95	5.08	0.96	3.81	0.64	3.10	0.62	1.71	0.29	1.65	0.24	14.15	0.65	162.07
10	70.10	0.65	11.70	3.59	1.90	0.04	1.21	0.54	1.38	5.91	0.05	1.86	24.22	26.64	6.05	24.29	6.17	1.23	6.92	1.24	7.74	1.54	4.43	0.69	4.35	0.62	3.23	0.58	116.13
11	3.03	0.02	0.61	1.12	1.94	0.00	19.76	30.37	0.00	0.00	0.01	42.24	2.89	4.16	0.52	1.50	0.25	0.10	0.23	0.04	0.23	0.06	0.17	0.03	0.15	0.03	11.16	1.21	10.35
12	40.53	0.07	0.86	17.82	16.63	0.39	6.01	13.50	0.65	0.17	0.00	3.05	1.64	2.52	0.27	0.86	0.15	0.07	0.17	0.03	0.18	0.04	0.13	0.02	0.12	0.02	7.85	1.39	6.22
13	43.63	0.05	1.07	27.47	13.73	0.43	3.41	6.91	1.00	0.39	0.00	1.78	1.98	3.75	0.47	1.58	0.28	0.08	0.24	0.04	0.22	0.05	0.12	0.02	0.13	0.02	8.69	0.90	8.98
14	57.44	0.64	11.44	2.48	2.22	0.15	6.23	11.24	0.91	1.61	0.11	5.30	40.53	73.46	0.39	32.77	6.91	1.44	6.78	1.11	6.61	1.37	3.86	0.59	3.62	0.55	6.49	0.64	188.98
15	62.84	0.63	13.72	2.65	3.47	0.11	2.32	3.00	2.02	4.08	0.24	3.07	62.49	94.85	10.33	29.92	4.36	0.88	3.28	0.49	2.11	0.41	1.02	0.15	0.77	0.11	46.90	0.69	211.17
16	92.30	0.15	3.57	0.11	1.31	0.16	0.13	0.37	0.22	1.74	0.01	0.37	6.30	9.96	1.31	3.78	0.58	0.19	0.40	0.09	0.31	0.07	0.18	0.04	0.20	0.03	18.53	1.16	23.43
17	95.15	0.04	1.28	0.11	1.43	0.19	0.00	0.22	0.22	0.78	0.01	0.20	15.72	26.05	3.20	10.29	1.73	0.34	1.48	0.25	1.66	0.35	1.06	0.16	0.98	0.15	9.26	0.63	63.43
18													62.51	134.88	16.64	50.62	8.45	1.47	5.23	0.96	3.85	0.75	1.98	0.35	1.81	0.27	20.01	0.63	289.77
19	69.00	0.54	14.71	4.22	0.46	0.04	0.63	1.38	0.50	3.87	0.13	4.03	44.51	84.57	10.39	34.53	5.94	1.01	4.18	0.72	3.02	0.56	1.52	0.28	1.60	0.21	16.12	0.59	193.04
20	74.47	0.08	14.18	1.06	0.77	0.03	0.34	00.24	2.44	4.20	0.07	1.59	42.78	70.85	9.51	28.69	4.52	0.62	2.89	0.51	2.48	0.54	1.68	0.30	1.81	0.28	13.69	0.49	167.46
21													31.80	83.42	8.24	23.21	3.76	0.49	2.52	0.48	2.16	0.45	1.34	0.25	1.49	0.23	12.36	0.46	159.84
22	74.42	0.22	14.17	1.37	0.96	0.03	0.93	0.45	0.45	4.26	0.02	2.31	82.55	231.62	20.04	51.80	9.05	1.06	4.99	0.84	2.11	0.42	1.21	0.32	1.41	0.23	33.92	0.44	407.75
23	68.06	0.60	16.59	1.57	1.99	0.05	0.55	1.08	1.98	4.04	0.02	2.31	43.45	87.99	11.37	38.84	6.29	1.36	4.09	0.63	2.56	0.55	1.46	0.26	1.48	0.23	17.01	0.78	200.56
24	71.66	0.25	14.48	0.70	2.43	0.10	0.96	1.00	6.04	1.60	0.10	0.44	52.76	96.32	11.90	37.47	5.75	1.12	3.69	0.60	2.27	0.47	1.28	0.25	1.45	0.23	21.08	0.70	215.56
25													24.85	51.57	6.67	23.73	4.90	1.22	4.42	0.80	5.00	1.08	2.99	0.49	2.96	0.43	4.86	0.79	131.11
26	65.07	0.35	16.19	4.42	0.07	0.07	1.86	4.16	4.10	1.31	0.17	2.02	19.64	42.59	5.33	18.32	3.05	0.92	2.02	0.29	1.30	0.26	0.69	0.13	0.72	0.11	15.80	1.08	95.37
27	64.97	0.43	15.87	2.75	1.46	0.47	1.29	3.86	3.41	2.64	0.25	2.10	13.16	28.22	4.06	14.35	2.74	0.87	1.92	0.30	1.26	0.25	0.64	0.12	0.57	0.09	13.38	1.11	68.55
28	62.23	0.43	17.54	3.16	1.90	0.55	1.58	3.85	3.07	3.05	0.25	1.66	12.14	26.10	3.63	13.14	2.36	0.81	1.59	0.23	1.01	0.19	0.47	0.08	0.37	0.05	19.01	1.22	62.17
29													16.88	30.98	3.92	12.59	2.46	0.76	1.98	0.37	1.45	0.29	0.74	0.13	0.68	0.10			
30													24.10	48.60	4.83	19.14	2.87	0.98	2.36	0.09	1.56	0.17	0.82	0.16	0.73	0.10			
31	71.66	0.25	14.48	0.70	2.34	0.10	0.96	1.00	6.04	1.50	0.10	0.44	21.88	48.34	5.00	21.85	4.07	1.04	3.26	0.28	2.73	0.42	1.60	0.31	1.58	0.23			

keynote: 1: biotite-plagioclase gneiss;
2: plagioclase fels;
3: amphibole gneiss;
4: dolomite-bearing biotite gneiss;
5: graphite diopside;
6: graphite-diopside marble;

7: graphite-calcite diopside;
8: amphibole-albite fels;
9: epidote;
10: sillimanite-garnet-quartz-microcline gneiss;
11: diopside marble;

12: magnetite-quartz-diopside;
13: magnetite-quartz-diopside;
14: graphite-calcite-actinolite gneiss;
15: calcite-biotite gneiss;
16: plagioclase quartzite;

17: migmatized quartzite;
18: biotite schist;
19-22: quartz-sericite schist;
23-24: sericite schist;
25: quartz-sericite schist;

26: quartz-biotite schist;
27-28: amphibole-biotite gneiss;
29: mica-quartz schist;
30: amphibole-biotite gneiss;
31: biotite fels. (nomenclature after Winkler, 1976)

Figure 3 Chondrite-normalized REE patterns for sediments from the Lushan terrain, the upper portion showing the chemical sediments, and the lower showing the clastics.

Figure 4 Chondrite-normalized REE patterns for sediments from the Wuyang terrain.

Figure 5 Chondrite-normalized REE patterns for sediments from the Xiaoshan Gp in the Xiaoshan terrain

Figure 6 Chondrite-normalized REE patterns for sediments from the Songshan, Jishan and Xiong'ershan terrains.

Figure 7 Eu/Eu^* versus ΣREE diagram for the sediments from the southern margin of the North China craton, showing contrasting sedimentary characteristics between pre-2300 Ma and post-2300 Ma.

were collected from the sediments with an age of 2300 Ma and all demonstrated positive Eu-anomalies and low ΣREE (Figure 6).

Jishan terrain

No. 29 is the only sample of the sediment from the Jishan terrain, which was formed before 3,000 Ma (Figure 2E, Table 2). Its REE pattern is quite similar to that of nos. 27-28 and also marked with low ΣREE and moderately positive Eu-anomaly (Figure 6).

Xiong'ershan terrain

No. 30, the sediment older than 2,550 Ma in age (Figure 2F, Table 2), displays positive Eu-anomaly (Figure 6). No. 31, the clastic sediment formed at about 2300 Ma, shows slight Eu-depletion (Figure 6).

Summary

Now we can say that the sediments younger than 2300 Ma are consistently depleted in Eu, the sediments older than 2300 Ma are marked by positive Eu-anomalies, and the sediments deposited at about 2300 Ma show slight Eu-depletion or no Eu-anomaly. This conclusion can be directly made from the illustration in Figure 7. The sediments older than 2300 Ma are entirely above the line of $\text{Eu}/\text{Eu}^*=1.00$ except No. 17 which was migmatized; the sediments younger than 2300 Ma are all below the line of $\text{Eu}/\text{Eu}^*=0.80$; and the sediments formed at about 2300 Ma are plotted between these two lines. In Figure 7, the sediments less than 2300 Ma are distributed on the right side of $100(\text{Eu}/\text{Eu}^*)/\Sigma\text{REE}=1$; while the sediments more than 2300 Ma lie on the left side of the line. Therefore, the sediments younger than 2300 Ma possess higher ΣREE than those older than 2300 Ma (Table 4).

Table 4 Contrasting in REE geochemical features between sediments earlier than 2300 Ma and those later than 2300 Ma

Age of sediments	Sample number	Eu/Eu^*	ΣREE	LaN/YbN
>2300Ma	9#	1.51	51.14	15.74
>2300Ma	11	1.45	59.71	19.41
2300Ma	4	0.90	68.38	6.61
<2300Ma	16	0.60	176.97	14.83

Figure 8 LaN/YbN versus ΣREE diagram for the sediments from the southern margin of the North China craton, showing contrasting sedimentary characteristics between pre-2,300 Ma and post-2,300 Ma sediments

Discussion

The differences in REE patterns between the Archean and the Proterozoic fine-grained clastic sediments (shales) were discussed in details by Taylor and McLennan (1985) who advanced that development of the K-granites at the end of the Archean had resulted in the Eu-depletion of the post-Archean sediments. According to their model, the REE characteristics of the clastics depend on their provenance. Therefore, the differences in REE in clastic sediments from the pre-2300 Ma and the post-2300 Ma strata should reflect a great tectonic change, i.e., the Archean-Proterozoic transition, occurring at about 2300 Ma in the area in question.

However, at the southern margin of the North China craton, none of K-granite masses older than 2200 Ma is known and the sedimentary Eu-depletion started from about 2300 Ma. Hence the sedimentary Eu-depletion, especially the chemical sedimentary Eu-depletion, can not be simply attributed to the formation of K-granite.

The sedimentary Eu-anomaly should be controlled by the nature of Eu and the sedimentary environment. It is well known that Eu^{2+} and Eu^{3+} are two natural states of Eu. The value of $\text{Eu}^{3+}/\text{Eu}^{2+}$ must be affected by $f\text{O}_2$. Therefore, the sedimentary Eu-anomaly can be illustrated by considering the changes in $f\text{O}_2$ (Table 3). When $f\text{O}_2$ is low, the aqueous anions will be prevailed by soft bases such as HS^- , S^{2-} , SCN^- , $\text{S}_2\text{O}_3^{2-}$, CO , CH_4 ; and the value of $\text{Eu}^{3+}/\text{Eu}^{2+}$ is low; Eu is dominated by Eu^{2+} . As a kind of acid, Eu^{2+} is softer than R^{3+} (trivalent REE ions, including Eu^{3+}) which are all typical hard acids. Eu^{2+} is easier than R^{3+} to combine with soft bases into stable complexes and to precipitate from water. R^{3+} will prefer to stay in water as ions. Thereby, sediments deposited in the reducing environment should be characterized by low ΣREE and positive Eu-anomaly. When $f\text{O}_2$ is high, Eu is dominated by Eu^{3+} and the anions will be hard bases such as OH^- , SO_4^{2-} , CO_3^{2-} and NO_3^- . As hard acids, Eu^{3+} and other R^{3+} tend to be combined with the hard bases (particularly OH^-) into stable complexes and to precipitate; while Eu^{2+} is likely to stay in water. Consequently, the sediments deposited under oxidizing conditions should be characterized by high ΣREE and Eu-depletion.

According to the above-discussed oxidation-reduction mechanism, the sediments, formed after 2300 Ma at the southern margin of

the North China craton and characterized by high ΣREE and negative Eu-anomaly, should have been deposited in the oxidizing environment; whereas those older than 2300 Ma featured by low ΣREE and positive Eu-anomaly should have been deposited in reducing conditions. Hence the oxic atmosphere should have appeared at about 2300 Ma.

Because the LR^{3+} are softer than HR^{3+} , the sediments formed in oxidizing environment should have lower value of $\text{La}_\text{N}/\text{Yb}_\text{N}$ than those in anoxic conditions in the light of the mechanism discussed above and shown in Table 3. In the studied area, the sediments older than 2300 Ma formed in reducing condition, should have higher values of $\text{La}_\text{N}/\text{Yb}_\text{N}$, whereas those later than 2300 Ma deposited in oxidizing environment have lower values of $\text{La}_\text{N}/\text{Yb}_\text{N}$, which is in general agreement with the facts shown in Table 4 and Figure 8. In Figure 8, the sediments more than and less than 2300 Ma are plotted on the left and the right sides of the line of $(\text{La}/\text{Yb})_\text{N} / \Sigma\text{REE} = 1/8$. Therefore, again the values of $\text{La}_\text{N}/\text{Yb}_\text{N}$ of the sediments from the southern margin of the North China craton indicate a great change in surficial environment at about 2300 Ma.

It should be also pointed out that the conclusion on the environmental change at about 2300 Ma can also be supported by the appearance of sulfates, BIFs with high $\text{Fe}^{3+}/\text{Fe}^{2+}$, red beds, glacials and other important changes at about 2300 Ma (Chen, 1989, 1990; Chen et al., 1991b, 1994, 1996; Condie, 1981, 1982; Schidlowski, 1976; Frakes, 1979; Hu, 1988; Eriksson et al., 1978; Hambrey and Harland, 1981).

Conclusions

(1) At the southern margin of the North China craton, the sediments more than 2300 Ma show positive Eu anomalies; the sediments less than 2300 Ma are characterized by Eu-depletion; and the sediments at about 2300 Ma demonstrate no obvious Eu-anomaly ($\text{Eu}/\text{Eu}^* : 0.80$ to 1.00).

(2) The values of ΣREE of the sediments less than 2300 Ma are much higher than those of the sediments more than 2300 Ma; the values of $\text{La}_\text{N}/\text{Yb}_\text{N}$ of the sediments later than 2300 Ma are lower than those of the sediments more than 2300 Ma.

(3) The differences in REE characteristics between the sediments more 2300 Ma and those less than 2300 Ma possibly resulted from the changes in the sedimentary environment. The sediments more than 2300 Ma (Archean), with low ΣREE , positive Eu-anomalies and high $\text{La}_\text{N}/\text{Yb}_\text{N}$, should have been deposited in the reducing environment; while those less than 2300 Ma (post-Archean), with high ΣREE , low $\text{La}_\text{N}/\text{Yb}_\text{N}$ and negative Eu-anomalies (in general, $\text{Eu}/\text{Eu}^* < 0.80$), deposited in the oxidizing environment.

(4) The sedimentary REE geochemical evolution strongly suggests that the oxic atmosphere appeared at about 2300 Ma, which is consistent with that of the studied sulfates, BIFs, red beds, glacials, etc.

(5) Besides the provenance of sediments, the sedimentary environment is the chief factor affecting the REE characteristics of sediments, particularly, of chemical sediments. The sediments formed in the reducing environment should be marked by positive Eu-anomalies, high $\text{La}_\text{N}/\text{Yb}_\text{N}$ and low ΣREE ; whereas those formed in the oxidizing condition should be characterized by clear Eu-depletion, low $\text{La}_\text{N}/\text{Yb}_\text{N}$ and high ΣREE .

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31st International Geological Congress

August 6-17, 2000

Rio de Janeiro, Brazil

The 31st International Geological Congress will be held in Rio de Janeiro, Brazil, August 6-17, in the year 2000. A Preparatory Commission has been working since 1995 to establish the Organizing Committee that will plan the scientific program and related activities of the Congress.

The theme of the Congress is "Geology and Sustainable Development: Challenges for the Third Millennium". Although the principal venue of the Congress is Brazil, other South American countries will be strongly involved in organizing the program and field trips and will host some pre- and post-conference events.

The scientific program will feature comprehensive, multi-disciplinary discussions of the important problems facing the geological sciences, and will strive to organize scientific sessions that reflect the interdisciplinary nature of today's science, emphasizing the importance of geological sciences to human society. In addition to highlighting the theme of the Congress, sessions will focus on frontier subjects and hot spots of international geoscientific research, with special attention to the unique geological conditions of the continent of South America.

Special symposia will feature invited papers dealing with the origin and history of the Earth; geosciences and human survival; environment and natural hazards; global changes and future environment; structure of the lithosphere and deep crustal processes; contemporary lithospheric motion; global tectonic belts; orogenic belts; basin analysis; energy and mineral resources for the 21st century; new technologies for the geosciences; and progress of international geoscience projects.

The Congress will also include an attractive program of short courses, workshops, and field trips. Field excursions will visit most of the geologic provinces of South America (including Antarctica), and will focus on the characteristic geologic features of the South American continent: major orogenic belts, large-scale sedimentary basins, mineral deposits, and a great variety of other geologic attractions.

The First Circular will be mailed in October, 1997. Further information about the Congress will be posted as it becomes available.

For the present, the principal point of contact is:

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