ORIGIN AND EVOLUTION OF THE AMAZONIAN CRATON

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The Amazonian craton appears to have been formed and modified by processes much like those of the better-known Precambrian cratons, but the major events did not always follow conventional sequences nor did they occur synchronously with those of the other cratons. Much of the craton's "Archean style" continental crust formation, recorded in granite-greenstone and high-grade terranes, occurred in the Early Proterozoic: a period of relative quiescence in many other Precambrian regions. Some of the Archean rocks originated in continental settings. The common Archean to Proterozoic transition in geological style did not occur here, but an analogous change from abundant marine volcanism to dominantly continental sedimentary and eruptive styles occurred later, during the~2 Ga Trans-Amazonian orogenic cycle.

Amazonian geology is summarized in Fig. 1 and Table 1 (see also recent reviews: 1-3a). The Amazon basin divides the craton into the Guiana (northern) and Guapore Shields, with Precambrian geology easily matched across the basin. Archean rocks in the northern (Imataca) and southeastern (SE Para, Brazil) extremities of the craton are separated along the northern and northeastern craton margins by an Early Proterozoic granite-greenstone terrane. Most of the remaining area is an immense anorogenic felsic igneous terrane, with felsic rocks belonging to or correlated with the Uatuma (1.7-1.9 Ga) and Parguaza (~1.5 Ga) cycles. The Early Proterozoic Central Guiana Granulite Belt (CGGB), divides both the adjacent granite-greenstone and Middle Proterozoic terranes in the Guiana Shield.

ARCHEAN TERRANES: The Imataca Complex includes medium to high-grade quartzo-felspathic paragneisses and iron formations accompanied by acid, intermediate, and mafic granulites and orthogneisses, dolomitic marbles, manganiferous metasediments, and anorthosites (4,5). Intense Trans-Amazonian deformation, metamorphism, and isotopic resetting obscure its Archean history (6). The Imataca Province also includes small areas with undated greenstone-belt lithologies. The province is in (thrust?) fault contact with the adjacent Early Proterozoic granite-greenstone terrane (7). It may be correlated with the Kenema-Man domain of west Africa (8), which also has Archean high grade rocks, iron formations, and fault contact with the adjacent Early Proterozoic terrane. They may once have been contiguous, and their faults may belong to the same system, according to paleomagnetic evidence (9).

Both low and high-grade Archean rocks are present in SE Para (~6°-10° S). Archean greenstone belts with pillow basalts and komatiites, amphibolite belts, and granitoid rocks and gneisses (10) form a basement to the low-grade Grao Para Group at Serra dos Carajas (Fig 1.). The Grao Para hosts the major Serra dos Carajas iron formation and was considered Proterozoic, but we recently obtained a rhyolite zircon age of 2.75 Ga for it. The group has an apparent minimum thickness of about 6 km and consists of bimodal, partially spilitized metavolcanic rocks overlain by 100-300 m of iron formations, overlain in turn by more basalts (10,11). Subalkaline basalts with flat REE patterns (10x chond) and basaltic andesites and shoshonites with LREE-enriched and flat HREE patterns predominate over rhyolites. The mafic rocks are unlike typical Archean basalts and basaltic andesites, but resemble those of Triassic rift rocks of eastern North America, consistent with their eruption through continental crust. They also resemble Proterozoic bimodal volcanics of the SW USA, which have been attributed to a rifted continental setting (12). Shales, tuffs, conglomerates, arkoses, quartz arenites, and iron, manganese, silica,

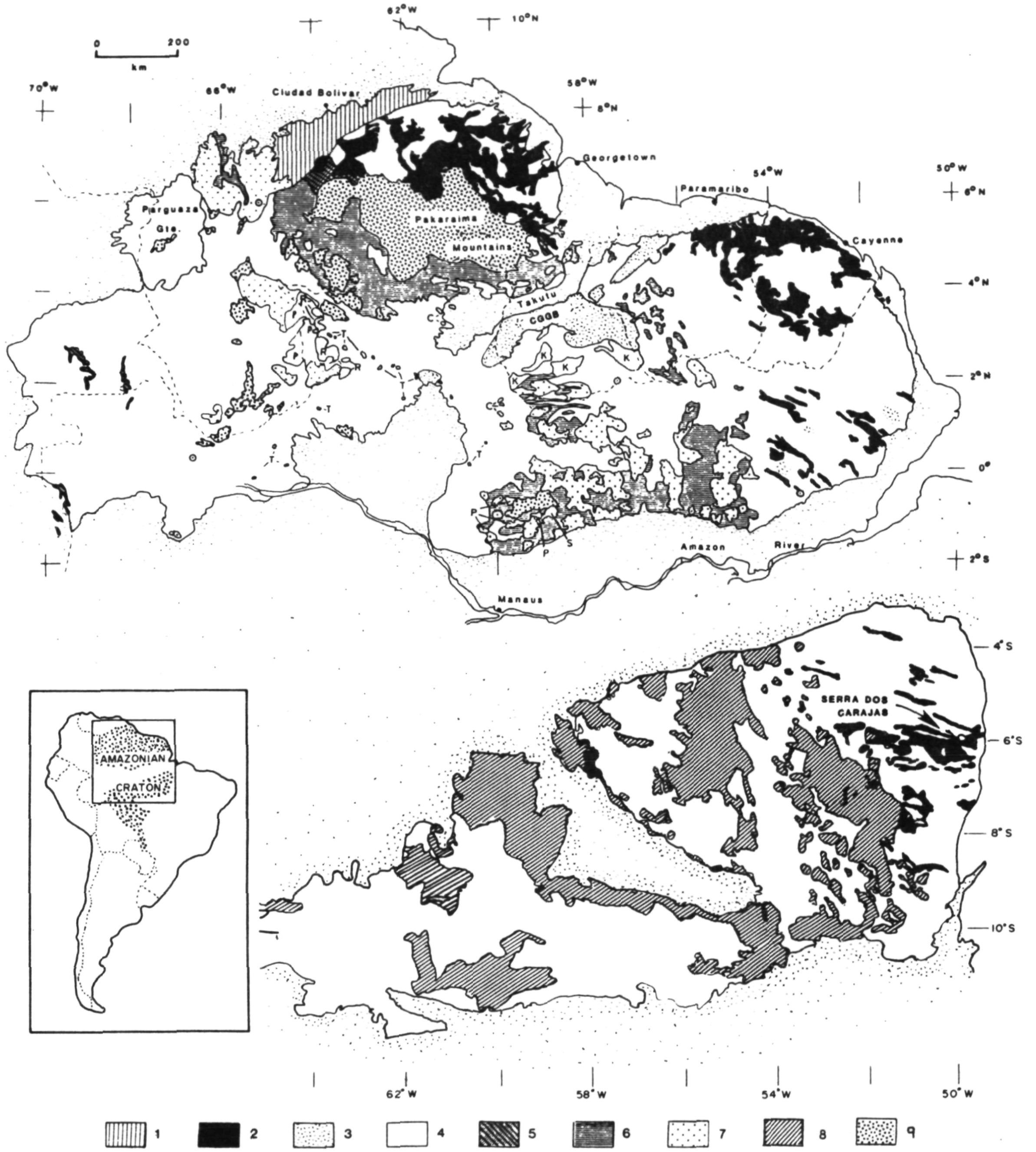

Figure 1. Outline geology of the Amazonian Craton (compiled from Anonymous, 1977; Bellizia et al, 1976; Gibbs and Barron, 1983; Metallogenic Map of South America, 1984; Schobbenhaus et al, 1981). Key: 1- Imataca Complex; 2- greenstone belts; 3- high-grade terranes; 4- undifferentiated granites and gneisses; 5- Middle Proterozoic pre-Uatuma sedimentary rocks; Uatuma Supergroup (6-8): north of the Amazon; 6- volcanics; 7- granitoid rocks; South of the Amazon, 8- Uatuma granitoid, volcanic and various sedimentary rocks; 9- Roraima Group sedimentary rocks; Other features: C- Early Proterozoic Cauarane Gp.; K- Early Proterozoic Kwitaro Gp.; P- Mid. Proterozoic Parquazan granites; R- Early Proterozoic Parima Gp. supracrustals; S- Later Proterozoic Seringa Fm; T- Trans-Amazonian Tapuruquara Suite mafic intrusives. Small circles- alkaline complexes.

TABLE 1: Major Precambrian Events of the Amazonian Craton.

	Basement Terranes			
Age (Ga)	Imataca Province	Northern Granite -Greenstone Terranes	Central Guiana Granulite Belt	Southeast Para, Brazil
0	Events of the Continental stage, superimposed on all of the basement terranes			
	Rifting, mafic igneous activity, and sedimentation in Amazon and Takutu basins			
1	K-Ar cooling Ages (.9 - 1.3 Ga), faulting alkaline complexes (ages uncertain)			
	Parguazan granite intrusions (1.45 - 1.55 Ga)			
	Mafic intrusions (1.6 Ga)			
	Continental sedimentation (1.65 - 1.9 Ga) and Uatuma cycle felsic intrusion and volcanism (1.75 - 1.9 Ga)			
	Mafic dike and sill intrusions (1.8 Ga)			
2	Trans-Amazonian Orogeny: metamorphism, mafic and granitoid intrusives			
	Events older than this apply to specific basement terranes			
		volcanism, sedimentation and granitic intrusion (2.1 - 2.25 Ga)	sedimentation and volcanism	clastic sedimentation (age uncertain)
			basement?	~~~?~~~
	Metamorphism (2.7 Ga) Igneous activity and iron fm. deposition?			Iron formation, volcanism, (2.7 - 2.8 Ga)
3	~~~?~~~			Gneisses and greenstone belts (ages uncertain)
	Protolith of some Imataca complex rocks (>3.4 Ga)			

and carbonate chemical sediments overlie the Grao Para Group in a pattern that is broadly concordant on a map scale, but may actually be unconformable. These sedimentary rocks might be Archean, or as young as Middle Proterozoic.

The boundary between the Archean crust of the Carajas region and the Early Proterozoic crust of French Guiana has not been adequately determined. Some suggest that it is located immediately north of Carajas, striking E-W (13). The similarity of map pattern of the (undated) belts of Amapa (0°- 2°N) and Carajas suggests that Amapa may be part of the same terrane, and may thus also be Archean. Gneisses and granulites that separate the Amapa greenstone and amphibolite belts have been considered by some to be Archean, though only tenuous isotopic evidence in support of this interpretation has been published (14).

Archean Amazonian iron deposits have features in common with both Algoma and Superior types. The dimensions and lateral persistence of both the Carajas and Imataca deposits are like those of Superior type; the association of the Carajas deposits with basalts is an Algoma-type feature.

EARLY PROTEROZIOC GRANITE-GREENSTONE TERRANES: All the autochthonous constituents of the northern Guiana Shield are thought to have emerged from the mantle during the Early Proterozoic. Greenstone belts are the oldest dated units; they have yielded 2.1-2.3 Ga U-Pb zircon and Sm-Nd ages (15-18). Gneisses and amphibolites in the same terranes have yielded similar and younger ages, and appear to be the intrusive associates and metamorphosed equivalents of the greenstone belt rocks (15,16,18-20a). Low initial $^{87}Sr/^{86}Sr$ ratios (<.703) are consistent with little involvement of older continental crust in the generation of the Trans-Amazonian granitoid and metamorphic rocks of the northern craton. The greenstone belts share similar lithostratigraphy: lower dominantly low-K basalts overlain by interstratified mafic, intermediate, and felsic volcanics of both tholeiitic and calc-alkaline suites; overlain by and interstratified with volcaniclastic greywackes, pelites, and chemical sedimentary rocks (21-23). There are regional differences in the abundances and varieties of volcanic and sedimentary rocks: felsic volcanics are irregularly distributed, and magnesian basalts and possible komatiites are particularly common in central French Guiana (23) and Amapa (24). Sea-floor metamorphism as well as very low to medium grade regional and contact metamorphism have affected these belts, and folded, crenulated, and cataclased metamorphic minerals indicate a complex, multistage metamorphic history. Most northern Amazonian greenstone belts have a randomly-branching synclinal map pattern, but the eastern Amazonian greenstones and granitoid rocks belts have been elongated WNW by late Trans-Amazonian deformation.

Clastic sedimentary rocks of continental provenance are infolded with several of the Amazonian greenstone belts. Some form synclinal cores to the belts of northern French Guiana and Amapa. Stratigraphic relations between these rocks and the underlying greenstone belts are not well resolved. The abrupt appearance of rocks of continental provenance in belts that otherwise appear to have been formed in ensimatic settings may be accounted for by unconformity; by more gradual tectonically-controlled changes in the sedimentary source areas and depositional environments; or, possibly, some of the associated greenstone belts may actually be ensialic. These enigmatic continental sedimentary rocks and the underlying greenstone belts have much in common with the west African Tarkwaian and Birrimian, respectively.

CENTRAL GUIANA GRANULITE BELT: This extends from western Suriname into Roraima Territory, Brazil, and consists of medium- and high-grade metapelites, cross-bedded quartzites, calc-silicates, marbles, and ferruginous and manganiferous quartzites, as well as interstratified mafic metavolcanic rocks, and metagabbros and metadolerites (25-27). These metamorphic rocks have not yielded reliable ages older than Early Proterozoic (20,28,15). Their stratigraphy and relation to the rest of the craton are poorly known. The abundance of sedimentary rocks of continental provenance in the CGGB is not consistent with correlation of its supracrustal precursors with the Early Proterozoic greenstone belts of the northern terranes. The lack of evidence of Archean ages argues against their correlation with the Imataca or SE Para Archean. They might be another product of continental emergence during the Trans-Amazonian.

TRANS-AMAZONIAN OROGENIC CYCLE: Originally defined by the concentration of plutonic and metamorphic rock K-Ar and Rb-Sr model ages at about 2.0-2.1 Ga throughout the Amazonian craton (29), some have extended the term to include rocks of the 1.7-1.9 Ga Uatuma cycle. However, these younger rocks belong to a discordant, though only slightly younger stage of continental development (30). The cycle marks the assembly of diverse crustal fragments into a continent, their common deformation, and the first development of continental environments on much of the craton. Dikes and structures of the late Trans-Amazonian and succeeding Uatuma cycle are extensive, and demonstrate that the crust behaved in a continental fashion. Like the Kenoran orogeny in Canada, the Trans-Amazonian included multiple stages of intrusion, including tonalitic plutonic and hypabyssal intrusions, generation of two-mica "S"-type granitoid rocks, and even the possible intrusion of some kimberlites prior to the final stages of metamorphism and deformation (23). The cycle ended with WNW and ENE-striking cataclastic deformation of both plutonic and metasupracrustal rocks prior to the deposition of the Uatuma Supergroup.

POST-OROGENIC EVOLUTION: Uatuma Supergroup and Parguaza granites and felsic volcanics, Roraima (1.85-1.65 Ga) and Gorotire Group arkoses, shales, quartz arenites and conglomerates , and 1.85 and 1.65 Ga mafic intrusives were emplaced in and on the upper crust of most of the Amazonian craton in the Middle Proterozoic. Only the northern and eastern margins and the CGGB lack evidence of this extensional and thermal modification, which affected both Archean and Early Proterozoic basement. The diffuse, 50-100 km wide Uatuma Sgp. boundary on the N and E cuts across older structures. Little is known about the ages of the pre-Uatuma basement in the vast central portions of the craton: few greenstone belts are exposed, and few ages in excess of 2 Ga have been determined. The Uatuma and Parguazan eruptions affected vast areas rather than linear belts, but there are indications that the ages progress from older (NE) to younger (SW), both in Venezuela (31) and in the southwest (32). Middle Proterozoic and younger faults and Paleozoic to Mesozoic dikes have reactivated Trans-Amazonian deformation zones, particularly the NE and ENE zone crossing the central Guiana Shield (33,34).

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REFERENCES: [1] Amaral, G. (1984) in F.F.M. de Almeida and Y. Hasui, O Precambriano do Brasil, Edgard Blucher, Sao Paulo, p. 6-35. [2] Santos, J.O.S., (and Santos and S.O.C. Loguercio) (1984) in Schobbenhaus et al. (eds.) Geologia do Brasil, DNPM, Brasilia, p. 59-91, 93-127. [3] Gibbs A.K., and Barron, C.N. (1983) Episodes 6, No. 2, 7-14. [3a] De Vletter, D.R. (1984), Contrib. Geol. Suriname 8: 11-30. [4] Kalliokoski, J. (1965) Geol. Soc. Amer. Bull. 76: 1027-1050. [5] Dougan, T. (1977) Precamb. Res. 4: 237-268. [6] Montgomery, C., and Hurley, P.M. (1978) Earth Planet. Sci. Lett. 39: 281-290. [7] Ascanio, G. (1981) Symp. Amazonico, Puerto Ayacucho, Venezuela, (preprint) 22p. [8] Cahen, L., Snelling, N.J., Delhal, J., and Vail, J.R. (1984) The Geochronology and Evolution of Africa. Oxford. 512 p. [9] Onstott, T.C., Hargraves, R.B., York, D., and Hall, C. (1984) Geol. Soc. Amer. Bull 95:1045-1054. [10] Hirata, W.K., et al. (1982) Anais Simp. Geol. Amazonia I, 100-110. [11] Gibbs, A.K., Wirth, K.R., and Hirata, W.K. (1984) unpblished 1984 field report. [12] Condie, K.C., and Nuter, J.A. (1981) Precamb. Res. 15: 131-155. [13] Cordani, U.G., Tassinari, C.C.G., and Kawashita, K. (1984) Ciencias da Terra, 9:6-11. [14] Jorge Joao, X., and Marinho, P.A. (1982) Anais I Simp. Geol. Amazonia, 2: 207-228. [15] Gibbs, A.K., and Olszewski, W.J., Jr. (1982) Precamb. Res. 17: 199-214. [16] Klar, G. (1979) Ph.D. Thesis, Case Western Reserve Univ., 163 pp. [17] Gruau, G., Martin, H, Leveque, B., Capdevila, R. and Marot, A. (1984) B.R.G.M., 19 pp. [18] Teixeira, W., Ojima, S.K., and Kawashita, K. (1984) D.N.P.M., II Symp. Amazonico, Manaus, Anais, p. 75-86. [19] Cannon, R.T. (1964) Geol Surv. British Guiana Bull 35, 83 p. [20] Priem, H.N.A., et al. (1978) in Zartman, R.E., (ed.), U.S. Geol. Surv. Open File Rep. 78-701, 341-343. [20a] Cordani, U.G., Teixeira, W., and Basei, M.A.S. (1975) Anais 10th Inter-Guianas Geol. Conf., pp. 53-54 (abstr). [21] Gibbs, A.K., O'Day, P.A., and Renner, R. (1984) Anais II Amazonian Symp. Manaus D.N.P.M., Brazil p. 39-52. [22] Veenstra, E. (1983) Contrib. Geol. Suriname, 7, 134 p. [23] Marot, A., et al. (1984) 10 Reunion Ann. Sci. Terre, Bordeaux, Soc. Geol. Fr. Edit. Paris. [24] Jorge Joao, X., et al. (1979) Geologia, 10, Secao Geol. Basica N. 7, DNPM, Brazil. 125 p. [25] Berrange, J.P. (1977) Inst. Geol. Sci., Overseas Div. Mem. 4, 112 p. [26] Kroonenberg, S.B. (1976) Geolog. Mijnb. Dienst Suriname, Meded. 25: 109-289. [27] Dahlberg, E.H. (1975) Geol. Mijnb. Dienst Sur. Med., 23:26-33.29. [28] Priem, H.N.A., et al. (1977) Geol. Mijnb., 56: 155-160. [28a] Spooner, C.M., Berrange, J.P., and Fairbairn, H.W. (1971) Geol. Soc. Amer. Bull. 82: 207-210. [29] Hurley, P.M., et al. (1968) Can. Jour. Earth Sci. 5: 633-638. [30] Santos, J.O.S. (1978) Acta Amazonica 8: 267-287. [31] Olszewski, W. J. Jr. and Gaudette, H. (1981) I Symp. Amazonico, Puerto Ayacucho, Venezuela, 15 p. [32] Tassinari, C.C.G. (1984) D.N.P.M., II Symp. Amazonico, Manaus, April 8-12, 1984, Anais, 439-446. [33] Gibbs, A.K. (1975) X Conf. Geol. Interguianas, Belem, p. 164-180. [34] Szatmari, P. (1983) Geology 11: 300-304. [35] Bellizzia, A., et al. (1976) Mapa Geologico Estructural de Venezuela. Ediciones Foninves, Venezuela. [36] Schobbenhaus, C., et al. (1981) Mapa geologico do Brasil ... 1:2,500,000. Brasil, D.N.P.M.

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