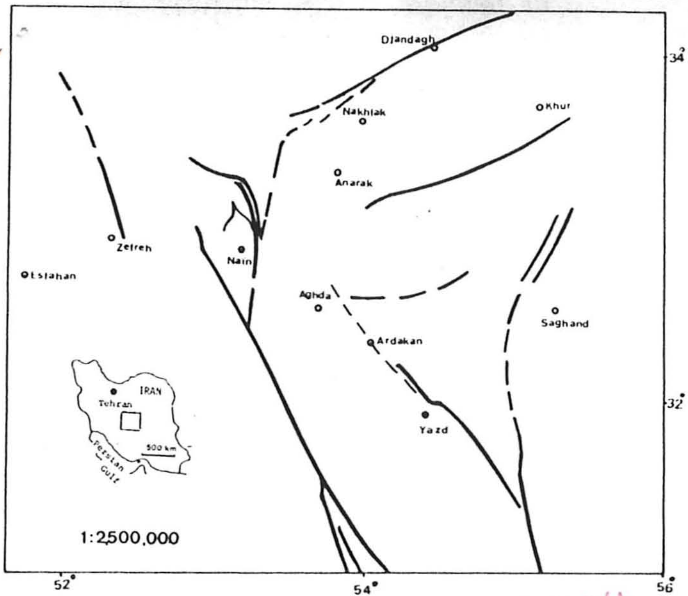

Figure 1.

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Genesis of Coal From the Viewpoint of Coal Petrology

The genesis of the microscopic constituents of coal (macerals) and of maceral associations (microlithotypes) representing various coal is discussed in light of recent advances that have been made in the study of coals and modern peats. Peat microscopy especially promoted the understanding of humification and biological gelification, both of which are decisive for the genesis of huminites/vitrinites in brown coals and hard coals respectively. Microbial activity during peatification has been testified by chemists, microbiologists and petrologists, and recently also by electron-microscopical observations in coals. It leads to the incorporation of lipid substances into the humic matter and, later, influences the chemical, physical and technological properties of vitrinites. The geochemical gelification transforms the huminites of brown coals into the vitrinites of bituminous coals and is probably caused by the onset of bitumen generation in coal. In this process, the hydrogel brown coal is transformed to the bitumogel bituminous coal. "Coal as a source rock for oil" has become an important research subject for coal petrologists (and oil exploration!). The formation of more or less liquid bitumen and its later cracking to gaseous hydrocarbons leads to "coalification jumps" of the macerals, especially liptinites and vitrinites and to the generation of secondary macerals like exsudatinite (bitumen) and micrinite (dead carbon). Bituminization in coal has been revealed by the use of fluorescence microscopy which also showed the presence of new liptinite macerals (bituminite, fluorinite and exsudatinite) and suggests a higher proportion of algal material in coals that was thought earlier. The genesis of various inertinites will probably become an increasingly important subject of research, especially with regard to "rank-inertinites" which seem to attain their high inertinitic reflectance initially during coalification.

Besides the origin of macerals, the origin of various coal facies in terms of maceral associations is considered in relation to the paleogeographic depositional milieu, the peat forming vegetation, paleo climate, water and nutrient supply, acidity, marine and calcareous influence and fire, with examples from Euramerican Carboniferous coals, Gondwana coals and Tertiary brown coals. Vegetations, water and oxygen supply (EH-conditions) are most important for the coal facies. Vegetation has been reconstructed with the help of paleobotany, including palynology, cuticular analysis and wood anatomy (in brown coals) and with the study of petrified peats preserved in coal balls. The microscopical investigation of botanically recognizable plant remains isolated from coals or accompanying rocks has been especially informative. However, the results of palynological and cuticular analyses should be evaluated with caution considering their varying resistance and, in the case of palynomorphs, their possible extrapalustral origin. Microscopical studies of modern peats derived from different types of vegetation growing in different hydrological environments have been very helpful in interpreting coal facies, especially in brown coals. The much disputed origin of brown coal lithotypes is considered in detail. For hard coals there seems to be agreement that coal layers rich in vitrite and liptinite-poor clarite were deposited in wet forest swamps, that microlayered liptinite-rich clarites are subaquatic humic muds and that inertinite-rich durites represent oxidized peats. The origin of liptinite-rich durites is controversial (either subaquatic muds or oxidized peats, the latter perhaps from raised bogs). A recent trend is the assumption that many if not all mineable coal seams have been deposited in raised bogs under ombrogeneous, oligotrophic conditions. Although raised bogs with a dense arborescent vegetation are known from Borneo it seems not probable that most seams (which were deposited in foredeeps or steadily sinking graben zones) are of ombrogenous origin although a succession from relatively wet and eutrophic to relatively dry and oligotrophic conditions may be true for occasional seams. But, as in modern peats, striking changes of seam facies are commonly caused by hydrological events, for example, inundations as a consequence of crevasses or of fires that burned the peat. The origin of the inertinite-rich Gondwana coals is discussed in relation to their specific climatic conditions and a comparison with sub-arctic peats is recommended. Coals influenced by marine and calcareous conditions are characterized by high contents in sulfur and pyrite, as well as hydrogen-rich vitrinites with a relatively low reflectance and high fluorescence, all due to a strong bacterial activity in peats of low acidity.

Proposals for further work are made in the conclusions.

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Outline on Early Proterozoic Crustal Evolution in São Francisco Craton, Brazil

The proposed review deals with the Early Proterozoic (E.P.) crustal evolution of the São Francisco Craton, which is a Late Proterozoic tectonically stable unit in the eastern part of the South American continent. Within the Craton, the oldest known rocks are Archean and they characterize granite-greenstone assemblages associated with medium- to high-grade metamorphic terranes.

Likewise, the Early Proterozoic domains are well represented by supracrustals rocks of greenschist to amphiobolite facies, many times included as greenstone assemblages (e.g., Itapicuru, Contendas-Mirante). In the southern portin of the Craton, they contain very important banded iron formations (e.g., Minas Supergroup), while in the northern part, conglomerates from the Jacobina Group contain syngenetic gold, and the Rio Capim metabasites include a highly concentrated sulfide level. Moreover, such E.P. domains are characterized by granulites and extensive granitization. The geologic framework of the Early Proterozoic is completed by intrusive granites (e.g., Campo Formoso, Porto Mendes(, alkaline rocks (Itiuba and Matola) and mafic dyke swarms (e.g., Uauá, Salvador, Pará de Minas, Bom Sucesso areas).

The regional structures within the E.P. provinces display conspicuous linear trends. In addition, the existence of some Archean "cratonic" nuclei bounded by the E.P. belts suggests that a certain duality in the tectonic processes occurred during the Early Proterozoic evolution. Such a tectonic style is also typical within these strongly developed linear belts, like the sigmoidal features observed for some supracrustals associated with Archean mantle gneissic domes.

According to the U-Pb, Sm-Nd, Pb-Pb and Rb-Sr radiometric data, the E.P. tectonic-magmatic events are concentrated in the 2.4–1.9 Ga time interval. Such events are defining two geochronological provinces surrounding an Archean stable domain. Within both provinces the basement rocks are exposed in two main areas (in the north and south of the Craton), partially covered by Mid and Late Proterozoic sequences.

The most important events are concentrated in the Transamazonian cycle (2.1–1.9 Ga), along which intensive reworking of continental crust have occurred, on mesozonal and catazonal conditions. This is supported by the relatively high $^{87}Sr/^{86}Sr$ initial ratio range (0.705–0.720) and μ_1 values (8.6–8.5) from the basement rocks. However, the Sr and Pb isotopic evidences combined with geochemical data also support, at that time, the existence of mantle-derived accretionary processes, particularly in the case of the Itabuna granulite belt. Besides, in terms of the Transamazonian tectonic context, the ages for the late tectonic alkaline intrusions (2.1 Ga) and of the post-tectonic granites (1.9–1.8 Ga) were followed by regional cooling of the basement rocks (1.9–1.7 Ga), so indicating events of final cratonization of the region.

Preliminary geochemical data are available for the majority of the above mentioned E.P. sequences. According to this, in the northern part of the Craton, for example, the Jacobina supracrustals may be interpreted as the upper pelitic unit of the adjacent gneissified and migmatized rocks. These paragneisses have granitic composition and REE patterns resembling those of S-type granites, with large negative Eu anomalies. In the same way, in the southern part of the Craton, E.P. granulites (Acaiaca area) are also considered as the higher grade metamorphic equivalent of the metasedimen tary rocks. In this part of the Craton, the exposed kinzigites may be interpreted as an anatetic residue from pelitic metasediments, as suggested by the chemical and petrographic studies.

Again in the northern part of the Crato, the low-Fe-Ti basal tholeiitic rocks units from the R. Itapicuru Group show LREE, Eu and HREE depletion similar to those of Morb, while its felsic to intermediate volcanics have a REE fractioned pattern with a small to pronunciated Eu anomalies. The latter pattern is comparable to those of modern cal-alkaline and high K-andesites and dacites. In addition, REE major and trace elements for the felsic to intermediate volcanics support a local derivation for the upper clastic sequence.

In the same geographic portion, the Contendas-Mirante volcano-sedimentary sequence indicated two geochemically distinct volcanic series: a tholeiitic and a transitional calc-alkaline. The correlation of ultramafic and anorthositic cumulates with the volcanic series also suggests two distinct mantle sources (of different composition) with varying conditions of partial melting and fractional crystallization.

Lastly, in the northeast part of the Craton, the Itabuna belt can be geochemically separated into four sequences: tholeiitic sequence; calco-alkaline sequence; shoshonitic basic rocks; and Fe-Ti rich basic rocks. The REE pattern for the calc-alkaline granulites is similar to Archean andesites or high-Al tonalites, while the tholeiitic and Fe-Ti-rich basic rocks resemble Archean tholeiites of the TH_2 type.

From the available data, the following model for the E.P. geodynamic evolution are being proposed:

The E.P. evolution probably started with crustal rifting of the Archean domains along the period 2.4–2.0 Ga with development of elongated intracratonic basins, simultaneously with the injection of mafic dyke swarms. During this period, important tectonic-magmatic events also occurred leading to reworking of continental crust and accretion from mantle sources. The most important of such events was the Transamazonian cycle along which about 30% of new crustal material was accreted from the mantle sources.

Depending on the intensity and combination of the dynamic processes, the E.P. intraplate tectonics are distinctive along the Craton: in its southernmost part, a large basin opening is supported by the vast stable shelf deposits (including BIFs) of the Minas unit. In the same way, a relatively large basin is suggested for the Contendas-Mirante sequence (in the northern part), but with its closing stage being probably associated to an island-arc system. In turn, the Jacobina unit may be considered as formed in an aborted rift, although the observed tectonic differences among the mentioned units can be also due to later E.P. crustal shortening which should be strongest in the cast of the Jacobina belt.

The complementary tectonic scenario is illustrated by the R. Itapicuru greenstone and the Itabuna belt, which are considered as a back-arc basin and a continental margin magmatic arc, respectively. Moreover, the E.P. shortening-type processes eventually allowed granite magma production due to subduction, as preliminary described.

Finally, the modeled tectonic evolution is consistent with the documented metamorphic complexity of the E.P. provinces. According to geothermobarometric data, temperatures and pressures were variable along the medium- to high-grade terranes ($T = 730$–$900\,°C$ and $Pt = 4/5$kb up to 10kb). Likely, this situation is suggested for the Rio Itapicuru supracrustals ($T = 400$–$600\,°C$ and $P_T < 2$ Kb), as well as for some BIFs in which the variability of the regional metamorphism is also supported by Oxygen isotope studies.

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Bolivian Global Geosciences Transects Program

The Bolivian Global Geosciences Transects Program (CC-7, ICL) involved three transects executed in the area of Bolivia (SA_5, SA_1 and SA_2 from south to north). These corridors are connected with the corresponding transects of the surrounding countries (Argentina, Paraguay, Brazil, Peru and Chile).

The transects represent compilations (in map and cross-sections, 1:1,000,000 scale) of existing geological and geophysical data along selected corridors crossing structures crucial for a better understanding of the nature and evolution of the lithosphere.

Each transect cover an area 100 km wide with a longitude variable—according to the different drafts (700, 1200 and 1400 km).

These three transects cut from west to east the following major geological domains: 1) Occidental Andes, a volcanic arc; 2) Altiplano a T-K sedimentary basin; 3) Eastern Andes and Subandean Ranges, a wide Paleozoic-Mesozoic sedimentary basin, folded and faulted; 4) Chaco Plains and "Llanos", a T-Q Sedimentary basin; and, 5) Brazilian Shield, a Precambrian cratonic terrane.

The strip maps shows the direct relation between the major geological terranes with the gravimetric anomalies. The interpretative cross sections shows the main geotectonics features and the Moho depths.

The Moho depths calculated thicken toward the central Altiplano reaching 70 km and Bouguer Anomaly about to ~400 miligals.

All the results are presented in a typical GGT display (one m^2 for each transect).

Figure 1.

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^{10}Be-^{9}Be and Geochemistry of Kruile–Kamchatka Arc

^{10}Be, a radioactive isotope ($t_{1/2} \approx 1.5 \times 10^6$ y) produced in the atmosphere, is transported to the earth's surface in rain and snow and concentrated in soils and sediments. ^{10}Be has never been found in pristine basalts from midocean ridges, oceanic islands, or continental rifts. In contrast, concentrations of 0.1 to 24×10^6 atoms/g have been measured in numerous pristine lavas from subduction related volcanoes (Brown et al., 1982; Tera et al., 1986). This clear-cut distinction, involving hundreds of samples, is a strong indicator of the incorporation of subducted sediments into magmas generated at subduction zones, an interpretation strengthened by combined measurements of ^{10}Be and the stable isotope ^{9}Be. Recent measurements of constant $^{10}Be/^{9}Be$ in mineral separates from historic volcanic rocks (Monaghan et al., 1985, 1988; Morris and Tera, 1987, in preparation) provide clear evidence that ^{10}Be was incorporated in the magmas prior to crystallization, and rule out sample alteration and cosmic ray bombardment as mechanisms for ^{10}Be incorporation in historic lavas.

The $^{10}Be/^{9}Be$ ratio can also be combined with other geochemical data to identify and characterize the end-members and geochemical processes responsible for the incorporation of ^{10}Be in island arc lavas (Morris and Tera, 1987, in preparation; Morris et al., in press). Thanks to ongoing American-Soviet cooperation, we are currently extending this endeavor to the Kurile–Kamchatka volcanic arc and provide here a progress report on this collaboration.

^{10}Be has been measured in 23 historic (1857–1983) lavas from the Kurile and Kamchatka volcanic arcs. The eight Kamchatka lavas are from six volcanoes; five are basaltic and three are andesitic. Fifteen analyses from the Kuriles represent nine volcanoes; eight are basaltic lavas and seven are andesitic. Results are presented in Figure 1. Kamchatka volcanoes have low