DATING HIGH-GRADE METAMORPHISM BY U-Pb, Sm-Nd AND K-Ar ISOTOPIC SYSTEMS: PALEOPROTEROZOIC I-TYPE GRANULITES FROM THE NORTHERN BORDER OF THE LUIS ALVES GNEISS-GRANULITE TERRANE, SOUTHERN BRAZIL

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The two principal Neo-Archean(?)/ Paleoproterozoic basement terranes exposed in southern Brazil are the Luis Alves Gneiss Granulite Terrane (GGT) and Atuba Gneiss-Migmatite Terrane which are surrounded by Neoproterozoic granite and metasedimentary belts (Figs. 1a, b): Piên Mafic-Ultramafic Suite and Piên-Mandirituba Granite Belt to the north, Dom Feliciano Belt to the south and Paranaguá-São Francisco do Sul Granite Belt to the east. The central and northern portion of the GGT and the southern border of the GMT are intruded by the Neoproterozoic Serra do Mar Plutonic-Volcanic Suite that is composed by alkaline-peralkaline granite and volcanic rocks. The northern border of the GGT and the whole GMT are affected by tectonic, magmatic and metamorphic processes of the Brasiliano/Pan-African orogenesis.

Regionally, the Luis Alves Gneiss-Granulite Terrane (GGT) is constituted by mafic, intermediate and felsic layered orthogranulites, pyroxene-free biotitic and amphibolitic gneisses, deformed calc-alkaline and alkaline granitoids and lenses of mafic and ultramafic rocks such as amphibolites, gabbros, pyroxenites and peridotites (Siga Jr., 1995; Basei et al., 1998, 1999; Fornari, 1998; Harara 2001). The granulites of sedimentary origin are rare and include garnet and rutile-bearing quartzites, cordierite-bearing kinzigitic gneisses and banded iron formations. The available U-Pb (conventional and SHRIMP) geochronological data (Siga Jr., 1995; Basei et al., 1998, 1999; Hartmann et al., 2000; Harara, 2001) on prismatic, rounded and elliptical zircons of the granulites, gneisses and deformed granitoids suggest the following ages for the high-grade metamorphism and synchronic magmatic periods: rare 2700 Ma, occasional 2400 and 2300 Ma and, frequent 2200 Ma, 2100 Ma and 2060 Ma. The U-Pb zircon ages of 2700 Ma and between 2400 and 2300 Ma are characteristic of the central and southern portions of the GGT while the ages between 2200 and 2060 Ma are characteristic of the northern portion of the GGT. The main geochronological data register the Paleoproterozoic metamorphic and magmatic events of the Trans-Amazonian orogenesis (Almeida et al., 2000). The K-Ar (biotite, amphibole) geochronological investigations (Siga Jr., 1995; Harara, 2001) carried out in the granulites and gneisses indicate ages around 1800 Ma and interpreted as the ages of the cooling and tectonic stability of the GGT.

Sm-Nd isotopic data (Siga Jr., 1995; Harara, 2001) revealed depleted mantle model ages (T_{DM}) between 2800 and 2500 Ma (Neo-Archean-Paleoproterozoic) for the granulites, biotitic and amphibolitic gneisses and deformed granitoids. These model ages indicate the time of the mantle differentiation of the GGT protholites.

The part of the northern border of the GGT, in the Rio Negro region (Fig. 1c), is constituted by LILE-depleted layered mafic, intermediate and felsic orthogranulites (norites, quartz norites, enderbites, rare charno-enderbites) and pyroxene-free biotitic and amphibolitic gneisses with compositions that include shoshonitic diorites/monzodiorites, quartz diorites and tonalites (Fig. 2). Lenses of biotite and amphibole-rich layered mafic orthogranulites and garnet-rich layered mafic and felsic orthogranulites occur within the mafic and felsic orthogranulites.

The mafic and felsic granulites are composed of quartz, plagioclase (oligoclase/andesine to labradorite), orthopyroxene, clinopyroxene, and minor amphibole, biotite, and interstitial microcline. The accessories minerals in both granulites are apatite, zircon, rutile and magnetite. The mafic and felsic granulites exhibit granoblastic, deformed granoblastic and lepido-granoblastic textures. The pyroxene-free biotitic and amphibolitic gneisses are composed of plagioclase, quartz, biotite, amphibole and epidote, minor K-Feldspar and rare orthopyroxene relicts. The accessories minerals are apatite, allanite, titanite, zircon and magnetite.

New U-Pb (conventional), Sm-Nd and K-Ar geochronological investigations carried out on biotite and amphibole-free mafic and felsic granulites, biotite and amphibole-rich mafic charnockites (isotropic appearance) and garnet-rich mafic granulites.

In the mafic granulites, elliptical (potato-type) and rounded (spherical-type) high re-crystallized metamorphic zircons, from the same rock, fall in the same discordia line and yielded similar upper intercept age of 2062 ± 65 Ma and one zircon concordant age of 2059 ± 6.6 Ma (Fig. 3).

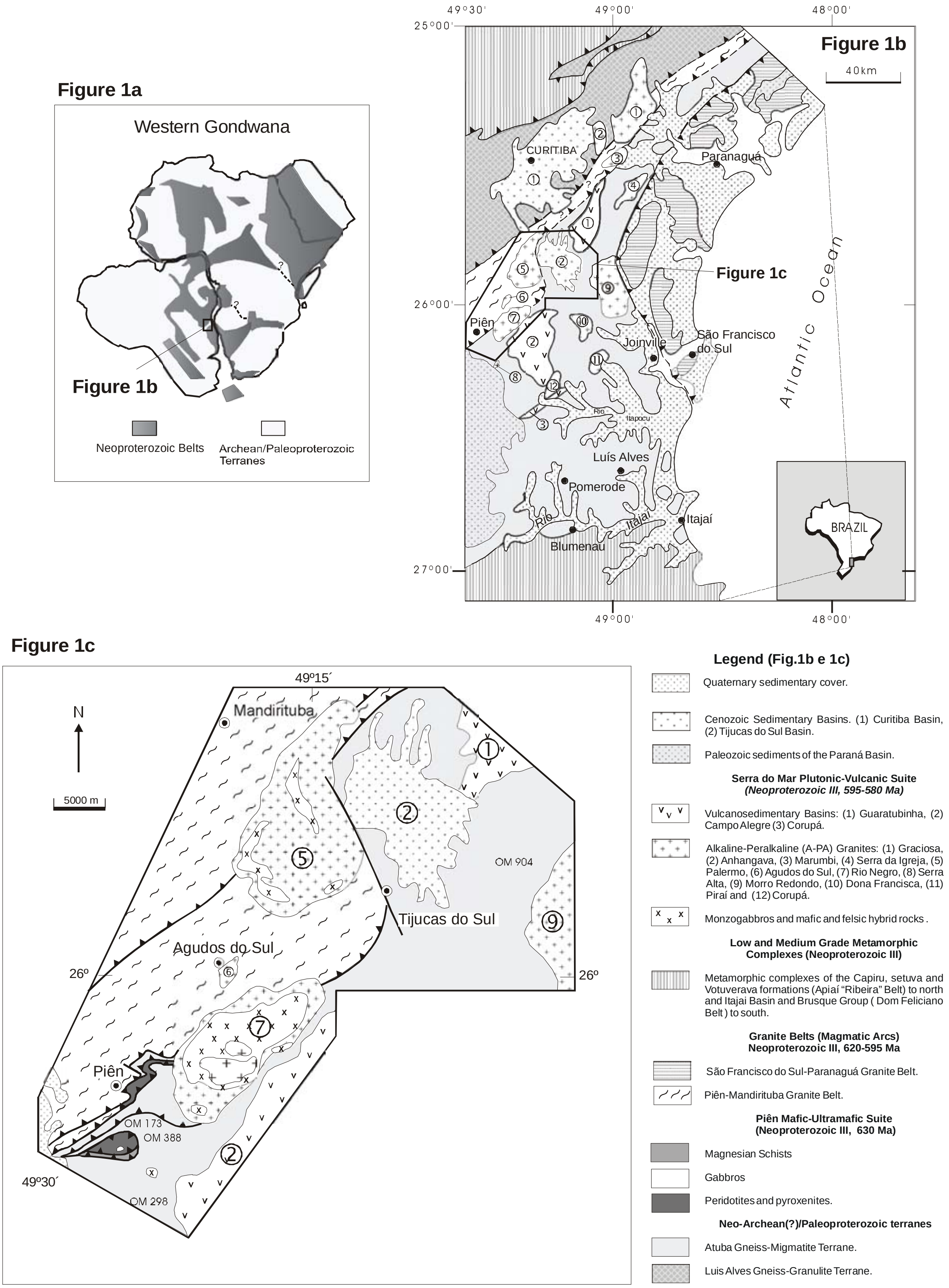

Figure 1. a) Sketch map of Archean/Paleoproterozoic Cratons and Neoproterozoic Belts of western Gondwana. Source: Modified from Unrug (1996). b) Geological map of south-eastern Paraná and north-eastern Santa Catarina states. Source: Siga Jr. (1995) and Harara (2001). c) Geological map of the Upper Rio Negro Region (PR-SC). Source: Harara (2001). The Samples dated by U-Pb and Sm-Nd methods, are indicated in the map.

In the felsic granulites, the elliptical zircons yielded an age of 2115 ± 31 Ma and the rounded (metamorphic) zircons, from the same rock, yielded upper intercept age of 2.060 ± 19 Ma (Fig. 4). The ages around 2060 Ma of the rounded metamorphic zircons, in both mafic and felsic granulites, and the concordant rounded zircon age of 2059 ± 6.6 Ma from the mafic granulites are interpreted as the ages of high-grade metamorphism of the northern border of the GGT.

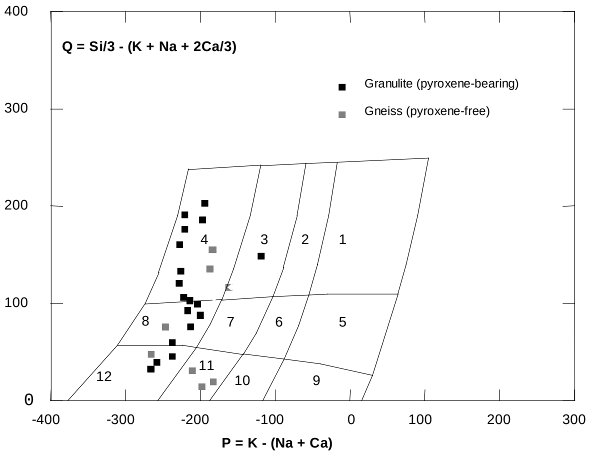

Figure 2. P-Q diagram (Debon & Lefort, 1983) for classification of igneous rocks applied to GGT rocks. Classification based on whole-rock chemical data (Harara 2001). 3. Granodiorites (Charno-enderbites), 4. Tonalites/Trondhjemites (Enderbites), 8. Quartz Diorites/QuartzNorites, 11. Monzodiorites/ Monzogabbros, 12. Diorites/Gabbros/Norites.

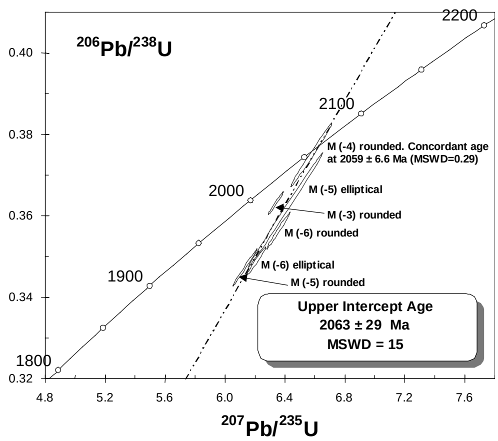

Figure 3. U-Pb Concordia diagram for elliptical and rounded zircons from mafic granulites. Sample OM 298.

The prismatic and long prismatic (acicular) zircons extracted from the biotite and amphibole-rich mafic charnockites fall on the same discordia line and yielded similar upper intercept ages of 2200 ± 7.3 Ma (Fig. 5). Based on the mineralogy, textures and typology of the zircon populations of these rocks, we interpret the age of 2200 Ma as the age of the igneous protholites of the granulite rocks from the northern border of the GGT.

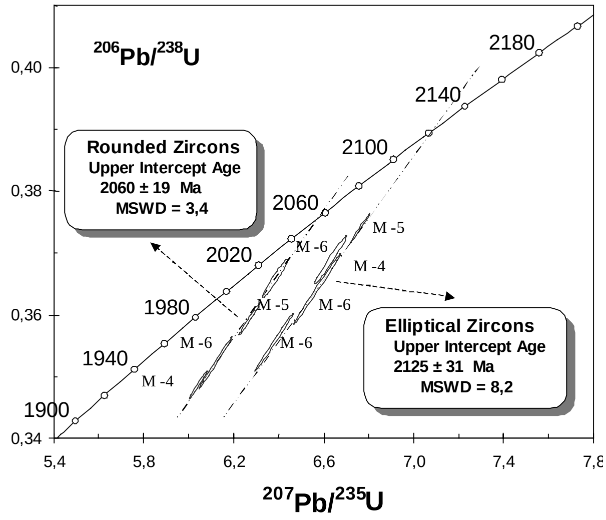

Figure 4. U-Pb Concordia diagram for elliptical and rounded zircons from felsic granulites Sample 388.

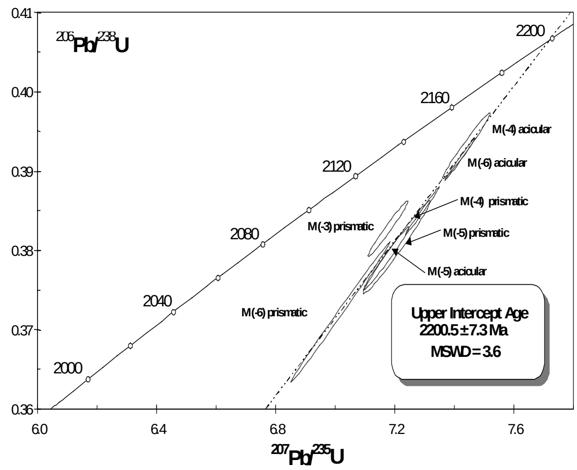

Figure 5. U-Pb Concordia diagram for prismatic and long prismatic (acicular) zircons of a biotite and amphibole-rich mafic charnockite. Sample OM 904.

Sm-Nd (whole rock, plagioclase and garnet) dating of garnet-rich mafic granulites yielded isochronic age of 1831 ± 17 Ma (Fig. 6). This age is similar to the K-Ar (biotite and amphibole) cooling ages, around 1800 Ma (Siga Jr., 1995; Harara, 2001) obtained in granulites and gneisses and interpreted as the cooling age of these rocks.

The time gap between K-Ar and Sm-Nd isochronic cooling ages of 1800 Ma and the U-Pb high-grade metamorphic ages of 2060 Ma suggest a slow cooling path for the GGT.

The GGT remained tectonically stable and cold until Neoproterozoic period, between 630 and 585 Ma, when its northern border was heated and affected by the adjacent Neoproterozoic subduction, collision and post-collision processes. These Neoproterozoic tectonic and metamorphic reactivations of the northern border of the GGT are suggested by pyroxene replacement by amphiboles, formation of epidote in the granulites, re-crystallization of biotite in the gneisses, parallelism of the tectonic foliations in the GGT with the tectonic foliations in the Piên Mafic-Ultramafic Suite and Piên-Mandirituba Granite Belt and resetting of the Paleoproterozoic K-Ar ages around 1800 Ma to Neoproterozoic ages between 650 Ma (amphibole) and 620 Ma (biotite).

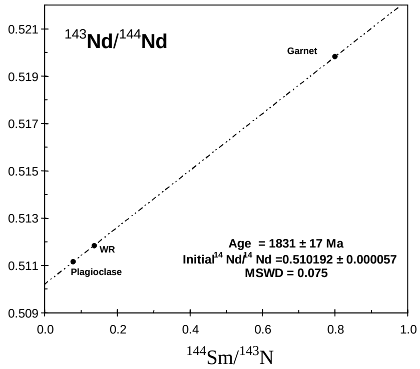

Figure 6. Sm-Nd isochron diagram for the garnet-rich mafic granulites.

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