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Deciphering thermal - tectonic evolution of early Earth : High-P rocks in Paleoproterozoic orogens

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Significant progress in metamorphic modelling has opened new opportunities to decode the P-T records of low-temperature metamorphic rocks (Yamato et al, 2007 and refs. therein) that comprise large tracts of exposed Archean and Paleoproterozoic terrains. We have seized these opportunities and report on the first discovery of blueschist metamorphic conditions (14 kb, 450°C) preserved within greenstone belts from a large Paleoproterozoic magmatic province in the West Africa Craton. Results obtained with two different thermodynamic approaches (multi-equilibrium vs pseudosection calculations) using updated and independent thermodynamic databases ("Tweeq" vs " Perple-X") are complementary. They yield a coherent metamorphic evolution (from M1 to M2), which reflect a temporal change in the thermal evolution during tectonic activity in the Birimian province.

M1 is a relic metamorphic event. It is characterized by early parageneses with T between 300-450ºC and low geothermal gradient (10-15ºC/km) throughout. High-P (14kb), low-T (450°C) chlorite-phengite assemblages have been clearly identified along low-T granitoids-greenstones contacts in the Fada N'Gourma area (sample Fa-33, Fa-34). Similar HP-LT conditions are also expected in the core of greenstones belts (work in process). They display tight P-T paths and clockwise isothermal decompressions. M1 assemblages are linked to a remnant fabric termed S1, probably developed during a short-lived event (D1) and predating the major pulse of granitoids intrusions at 2.15 Ga.

M2a is a contact metamorphism with dominant parageneses indicative of T ranging between 250-650ºC and moderate geothermal gradients (20-30°/km). M2a assemblages are linked to a regional NNE-SSW to NE-SW trending steeply-dipping planar fabric termed S2 and associated with magma intrusion. S2 is likely to occur during a long-lived D2 shortening event, probably starting after 2.15 Ga, and that will shape the greenstones basins into narrow belts (pure-shear regime?). Middle-P (6.5-8kb), high-T (550-650°C) assemblages have been extensively recognized along high-T granitoid-greenstones contacts (samples K451, A11, Te6C). M2a paths evolved through maximum prograde pressures of 1 kb (Fig.4). The retrograde paths, from 8 to <4.0 kb, define moderately high geothermal gradients of 30-50ºC/km. It is associated with regional static (cordierite corona around kyanite, Te6C) or dynamic (sigmoid inclusions in staurolite, K451) parageneses, across a large P-T range and with open clockwise P-T loops.

M2b is also part of the contact metamorphism but refers to retrogression apparently following continuously from M2a. It is characterized by multiple localised hydrothermal alteration events during a period of exhumation from 2 kb to <1 kb with T between 200-450ºC, and involving elevated geothermal gradients (30 to >50ºC/km). M2b assemblages are linked to more localized deformation characterized by steeply-dipping shear fabric named S2/C2 (dextral or sinistral shear planes).

Here we report evidence of an evolution through two contrasting thermal environments within a Paleoproterozoic Birimian belt surrounding the Eburnean Orogeny. There was initially a low dT/dP thermal regime (M1) that likely took place early in subduction zones, leading to the development of a regional high-P greenschist to blueschist metamorphism. This was then followed by high dT/dP thermal regime (M2) associated with magmatism and characterizing arcs, backarcs or orogenic hinterlands. It is thus expected that a modern plate tectonic regime involving horizontal motions of strong lithosphere and subduction of cold material already prevailed at 2.15 Ga in the WAC, predating the postulated “Neoproterozoic transition” (Brown, 2008).