Petrology, Metamorphic History and Structure of El Oro Ophiolitic Complex, Ecuador

Pablo DUQUE (1)

(1) Departamento de Geología, Escuela Politécnica Nacional, Casilla 17-01-2759, Quito, Ecuador

RESUMEN: El Complejo Ofiolítico El Oro, localizado en la parte SW del Ecuador, está constituido mayormente por rocas metamórficas de alta presión (eclogitas, esquistos pelíticos, esquistos azules, esquistos verdes). Sus condiciones de formación son 9 kb y 465°C. Se formó por procesos asociados con subducción bajo un grueso prisma acrecionario. La trayectoria P-T de subducción fué 45.41°C/kb. Su edad es 132Ma y fué intruido en rocas Jurásicas. Es parte de una extensa zona de melange.

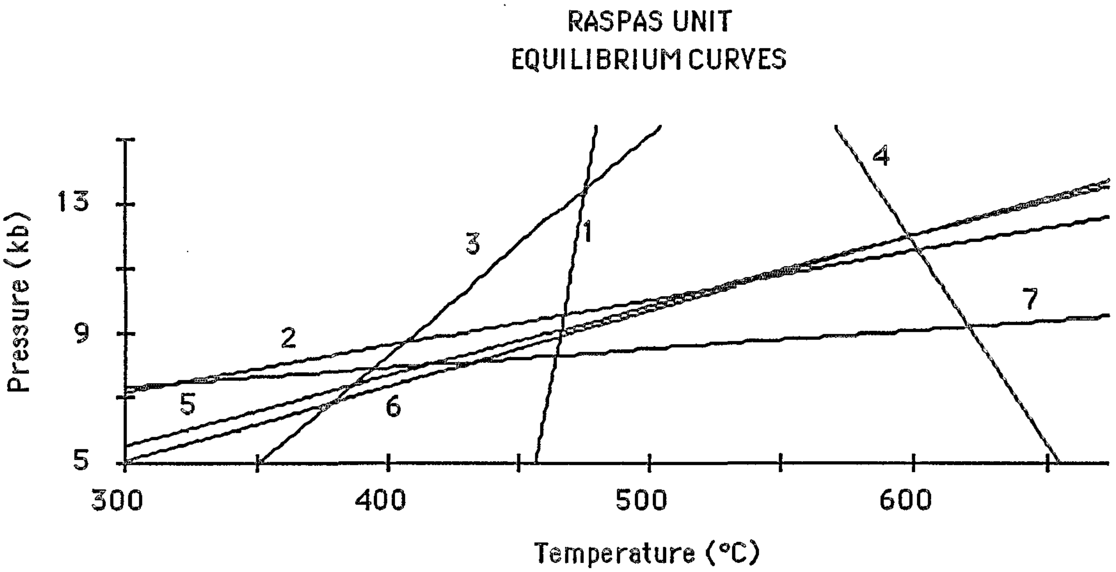
KEY WORDS: Ophiolitic complex, blueschist, eclogite, accretionary prism, melange, P-T subduction path.

INTRODUCTION

The east-west striking rocks of the El Oro province in southwest Ecuador form the northern part of the allochthonous Amotape - Tahuín block (Mégard, 1989). Recent geological mapping of the area (Aspden et al., 1993) interprets these rocks to form part of an accretionary prism complex, which contains elements of both 'continental' and 'oceanic' affinity. The rocks of the latter affinity include the El Oro Ophiolitic complex, which is ca. 45 km long and 5 km wide and is bounded to the north and south by the Palenque - El Guayabo and the Zanjón - Naranjo faults, respectively. The El Oro Ophiolitic complex comprises 3 units: the Raspas, the Panupali and the El Toro. The Raspas unit consists of pelitic schists, blueschists and eclogites, which were the first high-pressure rocks to be reported from the Andes (Duque, 1975, 1979, 1993; Feininger, 1980); the Panupali unit comprises greenschists and the El Toro unit corresponds to a variably serpentinized harzburgites. There are no transitions between eclogite and blueschist and Panupali greenschist. Greenschists within the Raspas unit are scarce and some of them show evidences of retrograde metamorphism. Chemical and mineralogical compositions are typical of subduction zone oceanic settings and can be classified as ophiolitic assemblages.

PETROLOGY

Self consistent results among numerous geothermobarometers applied to different Raspas rocks give a close range of peak metamorphic conditions (fig. 1). The Ellis-Green geothermometer (1979) based on calibrations for the exchange reaction clinopyroxene - garnet was used on rocks of eclogitic affinity. Temperature values were calculated in the range 5 - 15 kb and a best fitted curve was obtained by least - squares regression. The geobarometer plagioclase - clinopyroxene - quartz (Holland, 1980), using an ideal molecular solid solution for plagioclase and pyroxene, was applied on eclogite and the barometer garnet - plagioclase - kyanite - quartz, modified after Ghent et al. (1979), was used on pelitic schist. The best values obtained for the physical conditions of metamorphism in the Raspas unit rocks were 9 ± 0.5 kb at 465 ± 30°C. These results indicate that the high-pressure rocks recrystallized under equilibrium conditions within the Albite - Tremolite P-T field. Furthermore, they suggest that the Panupali greenschists belong to the high - pressure rocks and are products of prograde metamorphism.



1. Ellis-Green geothermometer
2. calcite = aragonite
3. Lw+Omph=Zo+pa+qz
4. chl+qz=Tc+ky
5. Plg(Ab_{93})=px(Jd_{34})+qz [PD311A1]
6. ga+ky+qz=Plg [PD156A]
7. ga+ru=Ilm+ky+qz

Fig.1: Equilibrium reactions applied in the Raspas unit to obtain its physical conditions of metamorphism (Lw=lawsonite, Omph=omphacite, Zo=zoisite, pa=paragonite, qz= quartz, chl=chlorite, Tc=talc, ky=kyanite, Plg=plagioclase, Ab=albite, ga=garnet, px=pyroxene, Jd=jadeite, ru=rutile, Ilm=ilmenite. PD311A1 and PD156A are samples in which the respective reaction was applied).

Whole-rock XRF analyses of Panupali greenschists and microprobe analyses of major phases in Raspas blueschists and eclogites, when compared by least-squares modeling, prove the bulk-rock chemistry to be essentially the same for all three lithologies. Oxygen fugacity and/or small compositional differences could be major influencing factors in the formation of either one of the rocks under the same metamorphic conditions.

METAMORPHIC HISTORY AND STRUCTURE

It is well established the connection between blueschist facies metamorphism and the low temperature - high pressure conditions encountered in subduction zones. Shreve and Cloos (1986) presented a thermal model in which blueschist facies conditions are encountered by the subduction slab under a thick accretionary prism. However, the return of the rocks to the surface is not well understood.

In order to develop a better understanding of the metamorphic history and of the interactions between tectonic and metamorphic processes, a P - T path of metamorphism was calculated using the analysis of chemical zoning in eclogite garnets. The estimated P-T path is 45.41°C/kb. The zonation scheme (fig. 2) shows that in the recrystallization process, heat was produced during compression, which is characteristic of subduction zones and, in general, of terranes in which cold rocks are emplaced over hot rocks.

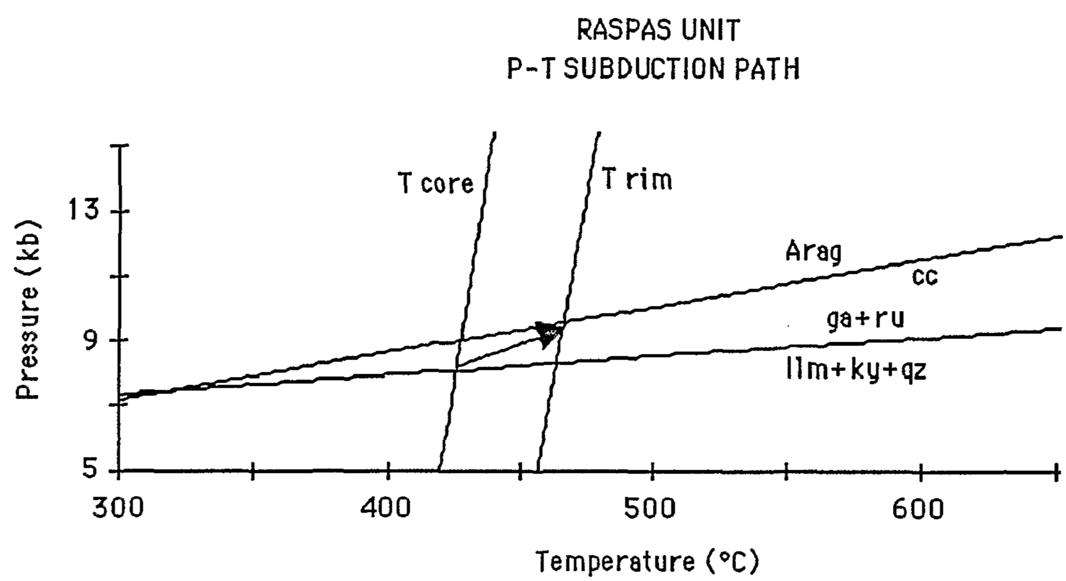


Fig.2: The arrow shows the possible P-T Subduction Path followed during the Raspas Metamorphism.

Duque (1975) estimates an average density of 3.03 gr/cm^3 for the overlaying rocks (mainly amphibolites metamorphosed in the high temperature / low pressure Abukuma type facies series). Using that figure, the formation conditions should be reached at 30 km depth under a thermal gradient of 13.8°C/km. That gradient belongs to a high - pressure facies series.

According to Ernst (1972), there is a secular change of subduction geotherms with time. The geotherms of higher pressure (ca. 12°C/km) correspond to late Cretaceous. If this is true, the Raspas geotherm suggests that the age of 132 ± 5 Ma (Feininger, 1980) is the age of the metamorphic event.

CONCLUSIONS

The high - pressure rocks of El Oro Ophiolitic Complex constitute an allochthonous block that recrystallized under the same metamorphic conditions in an active subduction zone. Upon cessation of the tectonic burial process that created the blueschist facies conditions (subduction), the package was carried upward by the partly serpentinized El Toro unit through the denser and older host rocks. The uplift had to be fast in order to preserve the high - pressure mineral assemblages and could involve complicated processes that occur in accretionary wedges. The age of the uplift could be similar to that of metamorphism. The emplacement of the El Oro Ophiolitic complex produced strong tectonism in the regional rocks that apparently are part of an extensive melange zone which can be traced throughout the Northern Andes (Aspden et al., 1993).

REFERENCES

Aspden, J., Bonilla, W., Duque, P., 1993. Final report of the El Oro Metamorphic Province Subproject. *Unpublished Report*, B.G.S. - CODIGEM, Quito, 115p.

Duque, P., 1975. Petrogénesis de unas rocas metamórficas de alta presión en la Provincia de El Oro. *Unpublished Thesis* , E.P.N., Quito, 66p.

________, 1979. Rocas metamórficas de alta presión de la Provincia de El Oro, Ecuador. *First Ecuadorian Geological Congress* ,Mem. I, 23-60.

________, 1992. Condiciones de formación de las rocas metamórficas de alta presión de la Formación Raspas, *Bol. Geol. Ecuat.*, 3, 1, 63-78.

Ellis, D.J. & Green, D.H., 1979. An experimental study of the effect of Ca upon garnet -clinopyroxene Fe-Mg exchange equilibria. *Contrib. Mineral. Petrol.*, 71, 13-22.

Ernst, W.G., 1972. Occurrence and mineralogical evolution of blueschist belts with time. *Amer. Jour. Sci.*, 272, 657-68.

Feininger, T., 1978. Geologic Map of Western El Oro Province, scale 1:50,000., *E.P.N., Quito.*

________, 1980. Eclogite and related high-pressure regional metamorphic rocks from the Andes of Ecuador. *Jour.Petrol.*, 21, 107-40.

Ghent, E.D, Robbins, D.B. & Stout, M.Z., 1979. Geothermometry, geobarometry, and fluid compositions of metamorphosed calc-silicates and pelites, Mica Creek, British Columbia. *Amer. Mineral.*, 64, 874-85.

Holland, T.J.B., 1980. The reaction albite = jadeite + quartz determined experimentally in the range 600-1200°C. *Amer. Mineral.*, 65, 129-34.

Mégard, F., 1989. The evolution of the Pacific Ocean Margin in South America north of Arica Elbow (18°S), In AVRAHAM, Z. B. (ed.) *The Evolution of the Pacific Ocean Margins, Claredon Press, Oxford*, 208-30.

Shreve, R.L., Cloos, M., 1986. Dynamics of Sediment Subduction, Melange Formation, and Prism Accretion. *Jour. Geophys. Res.*, 91, 10229-45.