Available geochronological data indicate that Arctic Shield in the Angmagssalik District underwent to main metamorphic events, the first at 2500 M.y. and the second at 1500 M.y.

Summing up petrographical and geochronological data the stages 1, 2, and 3 can be ascribed to the retrograde evolution connected to the oldest tectonometamorphic event, whereas stage 4 could represent the thermic peak of the later event.

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VILLA I.M.*, GIANELLI G.**, PUXEDDU M.**, BERTINI G.***, PANDELI E.*** - *Granitic dykes of 3.8 Ma age from a 3.5 km deep geothermal well at Larderello (Italy)*

Granitic dykes, apparently 2-3 m thick, were recently found intruding basement gneiss at a depth of 3.486 m b.g.l. in the geothermal exploratory well Monteverdi 7 drilled by ENEL (Italian National Electricity Board). The well is located 4 km SW of Serrazzano, outside the present-day exploitation area, near its western margin. An intrusive body has long been considered the heat source of the Larderello geothermal field (MARINELLI, 1963). The slow cooling rates revealed by radiometric data (DEL MORO et al., 1982), the large area (> 100 km²) enclosed by the 350°C isotherm at 3.000 m depth (BATINI et al., 1985), the wide negative gravity anomaly, the regional uplift of the Pliocene shore sediments (see DEL MORO et al., 1982) and the ubiquitous presence of a seismic reflecting horizon (BATINI et al., 1983), all indicate that this intrusive body is of batholithic dimension. The composition of the batholith was thought to be granitic because the post-tectonic late Alpine magmatism of Tuscany is mainly granitic (BARBERI et al., 1971). However the drilled wells did not encounter magmatic material until the early 1980s.

BATINI et al. (1983) first described a leucogranitic dykelet crosscutting basement micaschists in well VC II at 2.946 m depth b.g.l. BATINI et al (1985) date this dykelet at 2.9 Ma by K-Ar on the biotite of the gneiss immediately surrounding the dykes. The biotite was totally reset by the dyke emplacement to an age that is about 0.5 Ma younger than the equivalent biotite from the nearby well Sasso 22. From the K-Ar and Rb-Sr radiometric data on biotites of the latter well DEL MORO et al., (1982) concluded that the main body intruded more than 3.7 Ma ago. It is plausible that an extreme differentiate (the VC II leucogranite) was emplaced later. The discovery of a granite sample in well Monteverdi 7 confirms the validity of the geological model proposed. The granite appears as a gray-whitish finegrained rock, showing equigranular hypidiomorphic texture and made up of quartz (32.3 modal %), plagioclase (28.5%), K-feldspar (25.7%), biotite + chlorite (8.8%), white mica (3.7%), opaque minerals, cordierite, sillimanite, andalusite and accessories (1.0%). Plagioclase shows a continous normal zoning and a composition range of 20-45% An. K-feldspar is microperthitic and ofther shows granophyric textures at rims. Biotite is strongly chloritized. White mica includes both a primary mineral and a secondary microcrystalline type derived from the alteration of cordierite. Sphene appears as a rare secondary product associated with chloritized biotite. Sillimanite and green spinel probably represent relics of pelitic or metapelitic rocks partially molten by granite. The compostion of the Monteverdi granite is very similar to Tuscan late Alpine granites and almost identical to those of Gavorrano and Roccastrada.

A K-Ar age was obtained on a biotite freed from the chlorite by repeated gravity separation-methanol crushing. The resulting K content (7.4%) is satisfactory. Other analytical data are: $^{40}Ar_{rad}$ = 1.093 nl/g, or 21.1% of total ^{40}Ar; age = 3.8 ± 0.1 Ma. The inhole temperature is between 300°C, definitely lower than the closure temperature for biotites (see discussion in DEL MORO et al. 1982). This date is encouragingly consistent with the dates and conclusions of DEL MORO et al., 1982). This date is encouragingly consistent with the dates and conclusions of DEL MOTO et al. (1982) (emplacement age higher than 3.7 Ma, see above) and is therefore also in agreement with the regional apttern of the Tuscan granite cooling ages.

Conclusions. The following geological model is proposed. The Larderello geothermal anomaly was generated by a composite batholith surrounded by dyke swarms, emplaced more than 4 Ma ago. The younger age values found in the Larderello field, i.e. 1.6 Ma on a biotite from well San Pompeo 2 (BATINI et al., 1985) and 2.5 Ma from well Serrazzano Sperimentale (DEL MORO et al., 19827 have been explained in terms of distance from the thermal top and/or efficiency of cooling induced by hydrothermal circulation.

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ZORPI M.J.*, COULON C.*, ORSINI J.B.**, COCIRTA C.** - *Magma mingling, zoning and emplacement in calc-alkaline granitoid plutons*

The study of some Carboniferous orogenic granitoids plutons from Northern Sardinia reveals the close relationship betwenn their composition and the abundance of their mafic magmatic inclusions. The latter represents blobs of mingled basaltic magma. Most of the plutons are normally zoned with their felsic character increasing towards the core. This compositional trend goes parallel with a decrease in the number of the mafic inclusions. These characteristis are found in most calc-alkaline plutons throuhout the world. Moreover, in Sardinia, each studied pluton contains a population of mafic inclusions typified by a distinct FeOT/MgO ratio, suggesting that the emplacement of each intrusion is related to a single episode of mingling with a basaltic magma. On the other hand, a close chemical relationship

existing between the mafic inclusions and their host rocks shows that the basaltic and the granitic components are compositionally modified and that the granitic matrices are more or less hybridized.

Based on our observations, we suggest that in calc-alkaline plutons, zoning is the result of (1) compositional stratification developed in an early stage of the pluton's history, in an acid magma chamber located deeper that the intrusion level; (2) mingling and partial hybridization with a basaltic magma injected into the acid one. The intensity of hybridization of the granit host depends, among other factors, on the amount of its eclosed mafic inclusions.

A model of withdrawal of deep stratifield acid chamber injected by a basaltic influx is proposed to explain the normal zoning. In this hypothesis, the deeper layers of the reservoir are first drawn up, carrying blobs of mafic magma; they are followed by progressively higher and more felsic ones, poorer in mafic inclusions. The continuous emptying of the reservoir feeds the pluton at its level of final emplacement. A ballooning of the pluton results through the injection of successive magmatic pulses into the intrusion's core, accompanied by the deformation of the outer zones which are still hot and viscous. Hybridization mechanisms (migration of fluids diffussion, mechanical exchange of phenocrysts) probably occur at various stages of the pluton's history, i.e., in the deeper reservoir, during ascent and during ballooning.

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