Rev. Geol. Amér. Central, 18: 87-90, 1995

DIAGENESIS IN THE VOLCANICLASTIC SEQUENCES OF WESTERN NICARAGUA: MINERALOGICAL BREAKS AND TECTONIC IMPLICATIONS

Beatriz Levi[1) , Risto A. Kumpulainen[1) & Mauricio Darce[2)
[1)Department of Geology and Geochemistry, Stockholm University, S-10691 Stockholm, Sweden.
[2)Empresa Minera de Occidente P.O.Box RP-01 Managua, Nicaragua.

Southwestern Nicaragua is made up of several Cretaceous to Cenozoic stratigraphic units consisting of sedimentary rocks resting on a ophiolitic basement of Jurassic to mid-Cretaceous age (Fig. 1). The sedimentary sequence is dominated by volcaniclastic rocks which represent a shallowing-up succesion from deep marine turbidites to shallow marine and continental deposits (Seyfried et al., 1987; Kumpulainen, 1995). The volcaniclastic rocks are characterized by regional development of diagenetic mineral assemblages at zeolite facies (McBirney & Williams, 1965; Darce et al.,1989). Here, we outline these assemblages and their distribution in the different sedimentary units of southwestern Nicaragua (Fig. 2), based on X-ray diffraction and microscope study of 72 samples.

The secondary phases form cement and replace the glass of the volcanic clasts. They consist mainly of zeolites (modernite, heulandite, analcime, phillipsite and laumontite), silica minerals (tridymite, cristobalite and quartz), and clay minerals (smectite and swelling chlorite). The secondary minerals show a vertical zoning throughout the entire stratigraphic column and within each of the three lower units (Masachapa, Brito and Rivas; Fig. 2). Mineral assemblages are as a rule remarkably uniform in the volcaniclastic rocks at a given stratigraphic level, even in rocks of different grain size (tested in the Brito and El Fraile units).

Vertical zoning of diagenetic minerals in volcaniclastic rocks like in the sedimentary sequences of western Nicaragua, is typical of burial diagenesis, a process primarily controlled by an increase in temperature with depth. The formation temperature of the different assemblages can be estimated from static bottom-hole temperatures in deep wells in areas where burial diagenesis is taking place at present (Iijima, 1988). Such estimates indicate an increase in temperature from less than 60°C in the Las Sierras and El Salto units to c. 90°C in the lower part of the El Fraile unit, and an increase from c. 90°C to about 120°C from top to bottom in each of the three underlying units (Masachapa, Brito and Rivas). The mineral assemblages in the volcaniclastic rocks of the El Fraile unit are similar to those in the coeval Tamarindo lavas.

Figure 2 suggests that slight mineralogical breaks coincide with the unconformities separating Las Sierras from El Salto, El Salto from El Fraile, and El Fraile from Masachapa. There are clear breaks between Masachapa and Brito, and between Brito and Rivas, where rocks containing secondary assemblages of higher grade overlie rocks with lower grade assemblages, coinciding with an alleged regional unconformity separating the first two units, and a much discussed relationship (pseudoconformity?) between the last two units. Mineralogical breaks similar to those indicated above have been described from arc and forearc sequences in the Central Andes where they have been interpreted as the consequence of repeated diagenetic episodes separated by tectonic events of regional character (Levi et al., 1989). In Nicaragua these tectonic events probably correspond to island

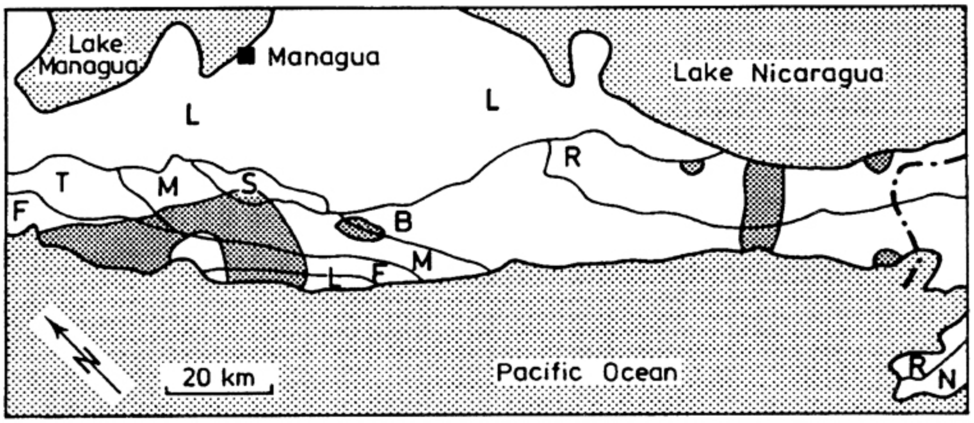

Fig. 1: Generalized geological map of southwestern Nicaragua and northwesternmost Costa Rica (simplified from Parsons Corporation, 1972) with ditribution of stratigraphic units and location of sampled areas (stippled). Rivas (R; Upper Cretaceous to Paleogene), Brito (B; Eocene) and Masachapa (M; Oligocene) are marine turbidites, El Fraile (F; Miocene) is deltaic to shallow water marine, Tamarindo (T; Miocene) is volcanic continental, El Salto (S; Pliocene) is shallow water marine to continental, and Las Sierras (L; Pleistocene) is volcaniclastic continental. The Nicoya Complex (N; Jurassic to mid-Cretaceous) is an ophiolitic unit only exposed in Costa Rica. Ages are from Parsons Corporation (1972) and depositional environments from Seyfried et al. (1987) and references therein, and Kumpulainen, 1995.

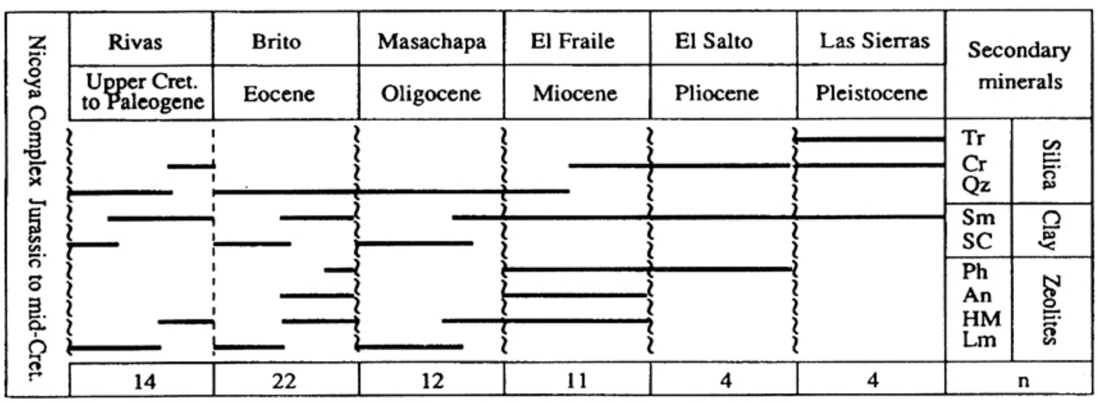

Fig. 2: Schematic distribution pattern of diagenetic minerals (excluding calcite) in the volcaniclastic rocks of westen Nicaragua. Structural relationships between units and ages are from Parsons Corporation (1972); the thicknesses of the units (see text) are not shown in the diagram. Wavy line = unconformity, broken line = conformity or pseudoconformity. The following abreviations are used: An = analcime, Cr = cristobalite, HM = heulandite (including clinoptilolite) and/or modernite, Lm = laumontite, Ph = phillipsite, Qz = quartz, Sm = smectite, SC = swelling chlorite and Tr = tridymite. Samples from the upper part of the Brito unit close to an alleged reverse fault that marks the contact towards the Masachapa unit contain laumontite instead of heulandite/modernite; these samples are not included in the diagram.

arc uplifts, tilting and sea level changes (Seyfried et al., 1987). It is therefore suggested that the clear mineralogical break between Brito and Rivas as well as between Masachapa and Brito could reflect tectonic events not easily recognized in the sedimentological record.

Based on estimated approximated thicknesses of the units treated here (Rivas = 2,800 m, Brito

= 2,600 m, Masachapa = 1,500 m, El Fraile = 1,300 m, and El Salto = 100 m; Parsons Corporation, 1972, and references therein; Kumpulainen, 1995), paleothermal gradients of about 15-20° C/km can be assigned for the Cretaceous to Oligocene diagenetic episodes. The magnitude of these gradients are typical for burial diagenesis of forearc sequences, but lower than the gradients (c.40° C/km) acting during the burial diagenesis in the volcanic arc (also at zeolite facies; Darce et al., 1989), and much lower than the gradients during the low-grade non-deformative metamorphism of ocean floor type of the Jurassic to mid-Cretaceous Nicoya Complex in Costa Rica (zeolite to greenshist facies; Levi, 1981; Gursky & Gursky, 1989).

Seyfried et al. (1991) suggested that a reversal in subduction polarity took place during the Campanian (from a situation with subduction towards the southwest to the present situation northeastward subduction), based on tectonic relations between the sedimentary sequences of western Central America and the Nicoya Complex. A high-pressure gradient indicated by the possible presence of pumpellyte-actinolite facies assemblages in shoshonitic lavas of the Metapán Formation in northeastern Nicaragua (Darce et al., 1989) is consistent with subduction of reverse polarity (compared to the present situation) at that time.

ACKNOWLEDGEMENTS

We are grateful to Glen Hodgson for donating some samples from his collection of Nicaraguan rocks, and to Maurits Lindström and Jan Olav Nyström for criticism of the manuscript. This note, published by permission of the Geological Society of Sweden, was prepared in December 1990 for a meeting on "Crustal evolution and metallogenesis of Nicaragua and adjacent areas" held in Stockholm. The study was financed by the Swedish Agency for Research Co-operation with developing Countries. (SAREC).

REFERENCES

Darce, M., Levi, B., Nyström, J.O. & Troëng, B., 1989: Alteration patterns in volcanic rocks within an east-west traverse through central Nicaragua. - J. South American Earth Sci., 2: 155-161.

Gursky, H-J & Gursky, M.M., 1989: Thermal alteration in the ophiolite basement of southern Central America. - In: J.R. Hein & J. Obradovic (eds.): Siliceous deposits of the Tethys and Pacific regions: 217-233; Springer-Verlag, New York.

Iijima, A., 1988: Diagenetic transformations of minerals as examplified by zeolites and silica minerals - a Japanese view. - In: G.V. Chilingarian & K.V. Wolf (eds.): Developments in sedimentology, 43, Diagenesis, II: 147-211. Elsevier, Amsterdam.

Kumpulainen, R.A., 1995: Stratigraphy and sdimentology in western Nicaragua. - Rev. geól. América Central, 18.

Levi, B., 1981: Low-grade non-deformational metamorphism in the Mesozoiç and Tertiary sequences of Costa Rica. - Pacific Geol.,15: 65-70.

Levi, B., Aguirre, L ., Nyström, J.O., Padilla, H. & Vergara, M., 1989: Low-grade metamorphism in the Mesozoic-Cenozoic volcanic sequences of the Central Andes. - J. Metamorphic Geol.,7: 487-495.

McBirney, A.R. & Williams, H., 1965: Volcanic History of Nicaragua. - Univ. California, Publ. in Geol. Sci., 55: 1-69.

Parsons Corporation, 1972: The geology of western Nicaragua. Nicaragua tax improvement and natural resources inventory project. - Final technical report. 4, Unpublished report: 220 pp.

Seyfried, H., Astorga, A., Calvo, C. & Laurito, C., 1987: Sequence response (cyclicity, biostratinomy, ichnofacies) to subsidence, sea level fluctuations, and exceptional events in Cenozoic forearc basins of southern Central America. - In: 8th Research Conference of the Society of Economic

Paleontologists (Gulf Coast Section) and Mineralogists Foundation (Innovative Biostratigraphic Approaches to Sequence Analysis: New Exploration Opportunities), Houston, Texas, December 1987: 131-141.

Seyfried, H., Astorga, A., Amann, A., Calvo, C., Kolb, W., Schmidt, H. & Winsemann, J., 1991: Anatomy of an evolving island arc: Tectonic and eustatic control in the south Central America fore-arc area. - Intern. Ass. Sedimentol., Spec. Publ.,12: 217-240.