Ber. Inst. Erdwiss. K.-F.-Univ. Graz	ISSN 1608-8166	Band 16	Graz 2011
IGCP 596 Opening Meeting	Graz, 19-24th September 2011		

What do latest Famennian and Viséan diamictites from Western Gondwana tell us?

STREEL, M.[1], CAPUTO, M.V.[2] & MELO, J.H.G.[3]

(1) Department of Geology, University of Liege, Sart-Tilman B18, BE 4000 Liège 1, Belgium; *Maurice.Streel@ulg.ac.be*
(2) Universidade Federal do Pará, Geologia, Av. Perimetral s/n, 66075-110 Belém-PA, Brazil; *caputo@interconect.com.br*
(3) Petrobras/Cenpes/Pdgeo/Bpa, Av. Horácio Macedo 950, I. Fundão, 21941-915 Rio de Janeiro, Brazil; *jhmelo@petrobras.com.br*

Late Devonian and Mississippian diamictites have been described from several regions of South America, their palynomorph content being partly studied in some detail. Lately, considerable controversy has arisen regarding their actual age and climatic versus sedimentary interpretations. We present here two miospore-based case studies focusing respectively on latest Famennian and on Late Viséan diamictites of the Parnaíba Basin (northern Brazil).

Varve-like rhythmites, usually very finely laminated sandstones, siltstones and shales with scattered clasts and tillites are known from outcrops and well cores of the latest Famennian upper Cabeças Formation, with sediments deposited under glacial and periglacial conditions (CAROZZI *et al*. 1975, CAROZZI 1980, LOBOZIAK *et al*. 1993, STREEL *et al*. 2001, CAPUTO *et al*. 2008*).* The investigated material comes from four samples of well 1-TM-1-MA, core 16. One of these (CAPUTO 1985, CAPUTO & CROWELL 1985, fig. 11E) is a laminite (varve-like rhythmite) composed of white very fine sandy and dark silty layers, each being approximately half a millimetre thick; eight layers have been macerated separately. The quantitative palynological analysis shows a miospore / miospore + acritarch ratio ranging from 40 to 70%. The palynomorph concentrations (number of specimens per gram of rock) suggest also some rhythmicity. Miospores progressively decrease from 4k to 2.5k in the silty layers (from 2.5k to 1k in the very fine sandy layers) before another rhythm starts. This could result from the changing intensity of water currents over basinal glacio-marine sediments deposited from subaqueous fans and related turbidity currents as well as from the calving of icebergs (CAROZZI 1980). Glacio-marine rhythmites have been described in the Carboniferous of Argentina (MILANA & LOPEZ 1998 and DEL PAPA & DI PASQUO 2007), but no analysis of the palynomorphs from the different rhythmites was provided. Tillites and associated silts allowed to identify 41 miospore taxa, most of which (29 i.e.70%) reworked from Middle and Late Devonian sediments. Among the other 12 taxa, *Vallatisporites vallatus* has the youngest first occurrence, at the base of the latest Famennian LVa (*lepidophyta-vallatus*) Zone, equivalent of the upper part or the entire LN (*lepidophyta-nitidus*) Zone according to MELO & LOBOZIAK (2001, 2003). The other 11 taxa could be also latest Famennian, but elsewhere they are known to range down into older parts of the Famennian. Curiously enough, the Middle Devonian miospores were found only in the tillite samples, whereas the Late Devonian miospores occur both in the tillites and laminites. It is suggested here that the LVa miospores represent the local vegetation of a deltaic and coastal environment, locally disrupted by some lobes of the contemporaneous ice cap (CAROZZI 1980). LVa miospores were distributed on the subaqueous fans and mixed with miospores reworked from underlying Frasnian strata of the upper Pimenteira Formation. Reworked Middle Devonian miospores might have originated from erosion and glacial carving of lower parts of the Pimenteira Formation (LOBOZIAK *et al*. 2000a). In the Parnaíba Basin, the LVa Zone characterizes latest Famennian sections of the Cabeças Formation in several wells (LOBOZIAK *et al.* 1992) and outcrops along the Tocantins River valley (LOBOZIAK *et al*. 2000b).

Cores from shallow boreholes penetrating the Mississippian Poti Formation, drilled for the construction of a dam on the Tocantins River (western margin of Parnaíba Basin, about 200 km west of well 1-TM-1-MA), include sandstones, siltstones and dark gray diamictites, very similar to the Late Devonian tillites that occur in the same well near the top of the Cabeças Formation. Palynomorphs have been extracted from 30 samples taken from 7 shallow wells drilled through diamictite sections ca. 26 m thick. All samples are extremely rich in well preserved palynomorphs, so that each slide prepared contains several thousands of miospores. Both Devonian and Mississippian miospores are present not only in the diamictites but also in some samples collected from silty strata on top of the diamictites, no difference being noticed along the cores. Tillites and associated silts allowed identifying 88 miospore taxa. Of these, 15 taxa (17%) are Late Viséan markers like *Schulzospora* sp. or *Raistrickia nigra.*

Other 37 taxa (42%) could be Late Viséan but are also known earlier in the Mississippian or even in the latest Famennian. Besides, 36 taxa (41%) are obviously reworked: 19 (22%) from the Tournaisian or the Upper Devonian and 17 taxa (19%) from the Upper or Middle Devonian. Acritarchs, where present, are presumably all reworked from the Devonian. MELO & LOBOZIAK (2000) assigned a Late Viséan age (coeval with the Holkerian and Asbian stages of the British Isles) to the Poti Formation, and correlated it with two Western European palynozones, *viz.*, TC (*tessellatus- campyloptera*) and NM (*nigra-marginatus*). MELO & LOBOZIAK (2003) related this formation to the Late Viséan Mag (*C. magnidictyus*) palynozone. In the Cortaderas Formation of Rio Blanco Basin (Argentina), which likewise contains glacial deposits, PEREZ LOINAZE (2007) defined the late Viséan MQ (*magnidictyus-quasigobbettii*) palynozone, which is correlative of the Mag palynozone of Brazil. The age of the MQ Zone is now constrained by recent (CÉSARI *et al.* 2011) radiometric data (335.99 +/- 0.06 Ma). This fits an earliest Asbian or latest Holkerian age determination, according to the Carboniferous time scales of MENNING *et al.* (2006) and OGG *et al.* (2008), respectively.

Reworked palynomorphs are well known to help finding the source area of sediments (STREEL & BLESS 1980). Their occurrence in diamictites has been emphasized since many years in Argentina (DI PASQUO & AZCUY 1997 and DI PASQUO 2007). As discussed above, diamictite datings should rely only on those species having the youngest first occurrences. However, WICANDER *et al.* (2011), working on an 18 m-thick diamictite in the lower portion of the Itacua Formation, in southeast Bolivia, recognized three successive miospore Devonian zones established in western Europe: LL (*lepidophyta-literatus)*, LE (*lepidophyta-explanatus*), and LN (*lepidophyta-nitidus*). They concluded that the diamictite sequence is to be envisaged as a composite that represents several deglaciation events. But, as mentioned by the authors themselves, the recognition of the LL Zone in that sequence was only tentative (it might be LE as well). On the other hand, in Brazil at least, the succession LE-LN is not easily distinguished and has been replaced by MELO & LOBOZIAK (2001, 2003) with the successive Rle (*R.lepidophyta*, with *i.a. Indotriradites explanatus* and *Vallatisporites verrucosus*) and LVa (*lepidophyta-vallatus*) zones, the former possibly representing an impoverished variant (ecofacies?) of the latter in places where *V. nitidus* is absent. It is true, however, that in western Germany, the bathymetry and palynofacies of the Stockum section (STREEL 1999 and STREEL *et al.* 2000) suggest that, during the LE-LN time (about 100 ky), the climatic system became more unstable, oscillating back and forth between regression (glacial) and transgression (interglacial) phases (BUGGISCH & JOACHIMSKY 2006). Detailed Mississippian biostratigraphic zonations comparable to the Western European palynozones are still in revision for South America (CAPUTO *et al.* 2008). However, alternating climates during 4 Ma certainly induced glacial and warm climates in close succession (BRUCKSCHEN & VEIZER 1997), allowing the warm-climate Paraca Flora (IANNUZZI & PFEFFERKORN 2002) to intervene between the Late Viséan and Serpukhovian ice ages (CÉSARI *et al*. 2011).

References

BRUCKSCHEN, P. & VEIZER, J. (1997): Oxygen and carbon isotopic composition of Dinantian brachiopods: Paleoenvironmental implications for the Lower Carboniferous of western Europe. - Palaeogeography, Palaeoclimatology, Palaeoecology, 132: 243-264.

BUGGISCH, W. & JOACHIMSKY, M.M. (2006): Carbon isotope stratigraphy of the Devonian of Central and Southern Europe. - Palaeogeography, Palaeoclimatology, Palaeoecology, 240: 66-88.

CAPUTO, M.V. (1985): Late Devonian glaciation in South America. - Palaeogeography, Palaeoclimatology, Palaeoecology, 51: 291-317.

CAPUTO, M.V. & CROWELL, J.C. (1985): Migration of glacial centers across Gondwana during Paleozoic Era. - Geological Society of America Bulletin, 96: 1020-1036.

CAPUTO, M.V., MELO, J.H.G., STREEL, M. & ISBELL, J.L. (2008): Late Devonian and Early Carboniferous glacial records of South America. - Geological Society of America Special Papers, 441: 161-173.

CAROZZI, A.V., FALKENHEIN, F.U.H., CARNEIRO, R.G., ESTEVES, F.R. & CONTREIRAS, C.J.A. (1975): Análise ambiental e evolução tectônica sinsedimentar da seção siluro-eocarbonífera da Bacia do Maranhão. - Ciência Técnica do Petróleo. Seção: Exploração do Petróleo, Rio de Janeiro 7: 1-48.

CAROZZI, A.V. (1980): Tectonic control and petroleum geology of the Paleozoic clastics of the Maranhao Basin, Brazil. - Journal of Petroleum Geology, 2 (4): 389-410.

CÉSARI, S.N., LIMARINO, C.O. & GULBRANSON, E.L. (2011): An Upper Paleozoic bio-chronostratigraphic scheme for the western margin of Gondwana. - Earth-Science Reviews, 106 (1-2): 149-160.

DEL PAPA, C. & DI PASQUO, M.M. (*2007*): Palaeoenvironmental interpretation and palynology of outcrop and subsurface sections of the Tarija Formation (Upper Carboniferous), Northwestern Argentina. - Journal of South American Earth Sciences, 23: 99-119.

DI PASQUO, M.M. (2007): Asociaciones palinológicas en las formaciones Los Monos (Devónico) e Itacua (Carbonífero Inferior) en Balapuca (Cuenca Tarija), sur de Bolivia. Parte 1. Geología, estratigrafía y asociaciones de la Formación Los Monos. - Revista Geológica de Chile, 34 (1): 97-137 and 34 (2): 163-198.

DI PASQUO, M.M. & AZCUY, C.L. (1997). Palinomorfos retrabajados en el Carbonífero Tardío de la Cuenca Tarija (Argentina): su aplicación a la datación de eventos diastróficos. - Revista Universidade Guarulhos, Série Geociências, Número Especial, 2: 28-42.

IANNUZZI, R. & PFEFFERKORN, H.W. (2002): A pre-glacial, warm-temperate floral belt in Gondwana (Late Visean, Early Carboniferous). - Palaios, 17: 571-590.

LOBOZIAK, S., MELO, J.H.G. & STREEL, M. (2000a): Latest devonian and early carboniferous palynostratigraphy of northern Brazil and north Africa - A proposed integration of western european and gondwanan miospore biozonations. - Bulletin des Centres de Recherches ExplorationProduction ElfAquitaine, 22 (2): 241-259.

LOBOZIAK, S., CAPUTO, M.V. & MELO, J.H. (2000b): Middle Devonian-Tournaisian miospore biostratigraphy in the southwestern outcrop belt of the Parnaíba Basin, North-Central Brazil. - Revue de Micropaléontologie, 43/4: 301-318.

LOBOZIAK, S., STREEL, M., CAPUTO, M.V. & MELO, J.H.G. (1992): Middle Devonian to Lower Carboniferous miospore stratigraphy in the Central Parnaíba Basin (Brazil), Annales de la Société Géologique de Belgique, 115: 215-226.

LOBOZIAK. S., STREEL, M., CAPUTO, M.V. & MELO, J.H.G. (1993): Middle Devonian to Lower Carboniferous miospores from selected boreholes in Amazonas and Parnaíba Basins (Brazil): additional data, synthesis, and correlation. - Documents des Laboratories de Geologie de la Faculte des Sciences de Lyon, 125: 277-289.

MELO, J.H.G. & LOBOZIAK, S. (2000): Viséan miospore biostratigraphy and correlation of the Poti Formation (Parnaíba Basin, northern Brazil). - Review of Palaeobotany and Palynology, 112: 147-165.

MELO, J.H.G. & LOBOZIAK, S. (2001): New miospore zonation of Devonian- Early Carboniferous strata in the Amazon Basin: a preliminary account. - *In*: MELO, J.H.G. & TERRA, G.J.S. (eds.): Cienc-Tecnic-Petrol, Exploraçao de Petroleo, 20: 99-107.

MELO, J.H.G. & LOBOZIAK, S. (2003): Devonian–Early Carboniferous miospore biostratigraphy of the Amazon Basin, northern Brazil. - Review of Palaeobotany and Palynology, 124: 131-202.

MENNING, M. *et al*. (2006): Global time scale and regional stratigraphic reference scales of Central and West Europe, East Europe, Tethys, South China, and North America as used in the Devonian–Carboniferous–Permian Correlation Chart 2003 (DCP 2003) - Palaeogeography, Palaeoclimatology, Palaeoecology, 240: 318-372.

MILANA, J.P. & LOPEZ, S. (1998): Solar cycles recorded in Carboniferous glacimarine rhythmites (Western Argentina): relationships between climate and sedimentary environment. - Palaeogeography, Palaeoclimatology, Palaeoecology, 144: 37-63.

OGG, J.G., OGG, G. & GRADSTEIN, F.M. (2008): The concise geologic time scale. - Cambridge University Press, 177 pp.

PEREZ LOINAZE, V.S. (2007): A Mississippian palynological bio-zone for Southern Gondwana. - Palynology, 31: 101-118.

STREEL, M. (1999): Quantitative palynology of Famennian events in the Ardenne-Rhine Regions. - Abhandlungen der Geologischen Bundesanstalt, Wien, 54: 201-212.

STREEL, M. & BLESS, M. (1980): Occurrence and significance of reworked palynomorphs. - Mededelingen Rijks Geologische Dienst, 32 (10): 69-80.

STREEL, M., CAPUTO, M.V., LOBOZIAK, S. & MELO, J.H.G. (2000): Late Frasnian-Famennian climates based on palynomorph analyses and the question of the Late Devonian glaciations. - Earth-Science Reviews, 52: 121-173.

STREEL, M., CAPUTO, M.V., LOBOZIAK, S., MELO, J.H.G. & THOREZ, J. (2001): Palynology and sedimentology of laminites and tillites from the latest Famennian of the Parnaíba Basin, Brazil. - Geologica Belgica, 3: 87-96.

WICANDER, R., CLAYTON, G., MARSHALL, J.E.A., TROTH, I. & RACEY, A. (2011): Was the latest Devonian glaciation a multiple event? New palynological evidence from Bolivia. - Palaeogeography, Palaeoclimatology, Palaeoecology, 305: 75-83.