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Late Devonian glacial deposits from the eastern United States signal an end of the mid-Paleozoic warm period

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ABSTRACT

A Late Devonian polymictic diamictite extends for more than 400 km from northeastern Pennsylvania across western Maryland and into east-central West Virginia. The matrix-supported, unbedded, locally sheared diamictite contains subangular to rounded clasts up to 2 m in diameter. The mostly rounded clasts are both locally derived and exotic; some exhibit striations, faceting, and polish. The diamictite commonly is overlain by laminated siltstone/mudstone facies associations (laminites). The laminites contain isolated clasts ranging in size from sand and pebbles to boulders, some of which are striated. The diamictite/laminite sequence is capped by massive, coarse-grained, pebbly sandstone that is trough cross-bedded. A stratigraphic change from red, calcic paleo-Vertisols in strata below the diamictite to non-calcic paleo-Spodosols and coal beds at and above the diamictite interval suggests that the climate became much wetter during deposition of the diamictite. The diamictite deposit is contemporaneous with regressive facies that reflect fluvial incision during the Late Devonian of the Appalachian basin. These deposits record a Late Devonian episode of climatic cooling so extreme that it produced glaciation in the Appalachian basin. Evidence for this episode of climatic cooling is preserved as the interpreted glacial deposits of diamictite, overlain by glaciolacustrine varves containing dropstones, and capped by sandstone interpreted as braided stream outwash.

The Appalachian glacigenic deposits are contemporaneous with glacial deposits in South America, and suggest that Late Devonian climatic cooling was global. This period of dramatic global cooling may represent the end of the mid-Paleozoic warm interval that began in the Middle Silurian.

1. Introduction

Workers have suggested that a protracted warm period, lasting 95 million years, characterizes Earth's climate from the Early Silurian to middle Early Carboniferous (Frakes et al., 1992). During the Late Devonian this warm period was punctuated by a brief interval of cooling (Copper, 1986; Stanley, 1988; McGhee, 1996). The global effect of this cooling has generally been considered to be minimal and brief (Hallam and Wignall, 1997), despite evidence of localized glaciation at higher latitudes in Gondwanaland (Caputo, 1985; Frakes et al., 1992; Crowell, 1999) and increased precipitation in the lower latitudes in Euramerica (Streel et al., 2000). Coincident with this episode of global cooling is an apparent sharp drop in global sea level (Johnson et al., 1985; Sandberg et al., 2002).

Evidence for the Late Devonian cooling episode is based primarily on localized glacial deposits documented from interpreted high latitude areas of South America (Caputo, 1985; Scotese, 2001). These deposits are proposed to have been restricted to latitudes greater than 70° (Frakes et al., 1992), but some authors have suggested that they were formed at as little as 55° (Isaacson and Sablock, 1990). During that time the eastern United States was situated on the southern end of the Euramerican (Old Red) paleocontinent. Euramerica was bordered on the southeast by the Acadian highlands. It has been suggested that this area, initially uplifted in the Silurian, was further elevated during the Acadian Orogeny in the Late Middle Devonian (Ettensohn, 1985). Earlier paleogeographic reconstructions based on lithologic and paleomagnetic data placed the eastern United States in equatorial latitudes (Woodrow et al., 1973; Van der Voo et al., 1979; Scotese et al., 1979; Ettensohn and Barron, 1981; Kent, 1985; Woodrow, 1985). More recent paleomagnetic data (Miller and Kent, 1988; Van der Voo, 1988) that eastern North America was at about 35° south of the equator. This interpretation is supported by studies of the distribution of platform carbonates, evaporites, and biotic reefs (Heckel and Witzke, 1979; Scotese, 2001; Copper, 2002). Thus, based on more recent reconstructions the eastern United States was situated at between 30° and 45° south of the equator in the Late Devonian.

In the central Appalachian basin of the eastern United States, extending from northeastern Pennsylvania to east-central West Virginia, Upper Devonian strata contain an enigmatic diamictite-bearing stratigraphic interval of rock. Termed “tilloid” by Sevon

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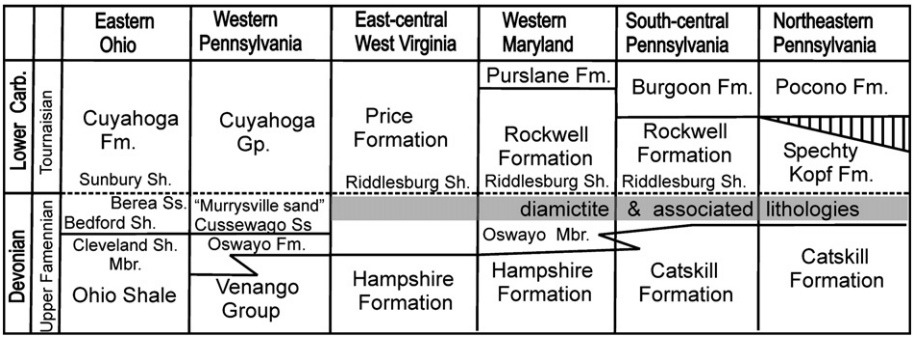

Fig. 1. Stratigraphic relations and nomenclature for Upper Devonian and Lower Carboniferous strata of the Appalachian Basin (Berg et al., 1983; Bjerstedt and Kammer, 1988; Berg, 1999; Brezinski, 1999).

(1969), this diamictite was attributed to highly localized debris flows (Sevon, 1969, 1979; Bjerstedt and Kammer, 1988). Reexamination and redescription of known exposures, as well as identification of new exposures of the diamictite, reveal an association of lithofacies that is atypical of debris flow deposition. Thirty-six studied localities display characteristics that are best explained by glacial processes. This assertion, when considered in a global context, suggests dramatic and drastic changes in Earth's climate that heralded the end of the Devonian. The palaeogeographic and stratigraphic position of this climatic cooling episode within the mid-Paleozoic warm mode may call into question whether the warm mode extended into the Late Mississippian as previously believed.

2. Stratigraphy, age, and correlation

The Spechty Kopf Formation of northeastern Pennsylvania and the equivalent Rockwell Formation of south-central Pennsylvania and western Maryland span the Devonian–Mississippian boundary (Berg, 1999). In distal areas these formations intertongue with marine strata and are underlain by the red clastic strata of the Catskill Formation and its equivalent in Maryland and West Virginia, the Hampshire Formation (Fig. 1). Sevon (1969) recognized a polymictic diamictite locally within the lower Spechty Kopf Formation (Sevon, 1969). A similar facies was subsequently recognized within the lower Rockwell Formation in south-central Pennsylvania and western Maryland (Sevon, 1979; Bjerstedt, 1986). Recent field work has identified this same rock type in east-central West Virginia, where it is present at the top of the Hampshire Formation (Fig. 1).

Previous studies assigned either a Late Devonian (Berg, 1999) or early Mississippian (Bjerstedt, 1986; Bjerstedt and Kammer, 1988; Suter, 1991) age to the diamictite succession. Although no detailed biostratigraphic studies have been published on the diamictite interval, Sevon et al. (1997) discussed palynological data that suggest that the interval falls within the Late Devonian *pusillites–lepidophyta* Miospore Zone. This miospore zone is partially equivalent to the *Siphonodella praesulcata* Zone, the terminal Devonian conodont zone. These faunal zones have been documented elsewhere in the Appalachian basin within the Bedford Shale and Berea Sandstone interval of northern Ohio (Streel and

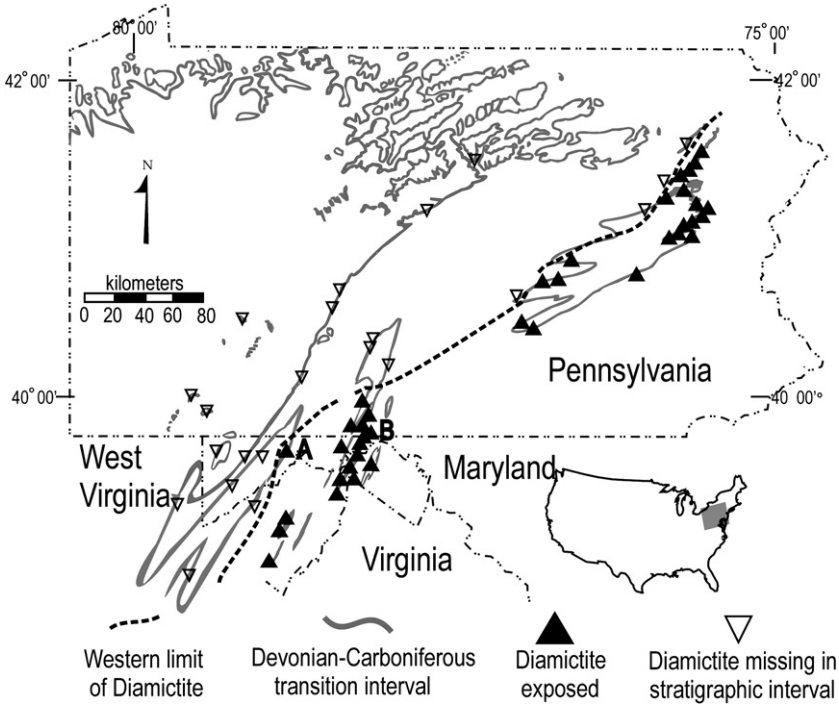

Fig. 2. Location of exposures of the diamictite sequence (solid triangles) and areas where diamictite is absent from the stratigraphic interval (inverted open triangles). Outcrop pattern of the Devonian–Mississippian transition in the central Appalachians (from Brezinski, 1988; Berg, 1999). Letters refer to stratigraphic sections referred to in text.