Geologie en Mijnbouw **74:** 237–240, 1995.

Between Diluvium and Deluge: the origin of the Younger Dryas concept (extended abstract)

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Received 1 March 1994; accepted in revised form 30 June 1995

Dryas octopetala

The name *Dryas octopetala* for the Rosaceae species Mountain Avens was first used by Linneaus in his 'Flora Lapponica' (1737, Salomon Schouten, Amstelaedami): 'Dryadem a Dryadibus Deabus quercum dixi hanc plantam, cum folia quodammodo formam foliorum *Quercus* exhibeant.' Because the leaves of *Dryas* somewhat resemble the leaves of oak, the species was named after the Greek 'druas', dryad or tree nymph, who's name in turn is derived from the Greek word for oak 'drus'. *Octopetala* refers to the 'eight petals' of the flower. In an earlier work Linneaus had used the name *Dryadaea* (1735, Systema naturae sive Regna tria Naturae systematice proposita per classes, ordines, genera & species. Lugduni Batavorum apud Theodorum Haak). Before Linnaeus, many other scientific names have been in use for the species (Marzell 1951), including *Caryophyllata* and *Chamaedryos* (1680), *Chamaedrys* (1623), *Argentina Mompelliaca*, *Herba Cervi* (1574) and *Cervaria* (1561). *Dryas* certainly was the better alternative.

The last deglaciation is characterized by rapid climatic fluctuations, which were completed with the Younger Dryas, a very pronounced cold pulse. Study of these climatic shifts may shed light on positive feedback mechanisms in the climate system. This paper summarizes the historical background of the concepts of climatic change and Younger Dryas, illustrating that many topical ideas had their precursors in the history of climate research.

The Younger Dryas marked the end of the Pleistocene (meaning 'very much new'), the 'age of cycles', in which an alternation of glacial and interglacial periods had taken place. It had been the era of human origin, evolution and dispersion, culminating in *Homo sapiens sapiens*. Mankind had experienced time as a cycle, as eternal repetition. The subsequent Holocene (meaning 'completely new') may be characterized as the 'age of progress'. By 10 000 BP modern humans had colonized all the continents except for Antarctica, and a gradual spreading of agriculture, permanent settlement, industry and science followed. Judaeo-Christian tradition changed the concept of time from cyclic to linear and irreversible (Eliade 1955).

Until some decades ago, the Pleistocene was commonly referred to as the 'Diluvium' (= 'big flood'). This name was derived from the Biblical flood (Genesis 6:5–9:7), the event that for centuries had been considered as the major cause of many unusual geological, geomorphological and biological phenomena. With the Renaissance the medieval ties between theology, philosophy and science were severed and natural sciences started to find their own way. Leonardo da Vinci (1452–1519) was amongst the first to question the Biblical flood as an explanation for the presence of fossil marine organisms on the continent. In his Notebooks he remarked: 'the cockle is a creature incapable of more rapid movement than the snail out of water ... it will travel between three and four ells in a day; and therefore with such a motion as this it could not have travelled from the Adriatic Sea as far as Monteferrato in Lombardy, a distance of two hundred and fifty miles in forty days, – as he has said who kept a record of that time.'

The fading of the flood concept, however, was a long-term process. Still in 1800 Von Humboldt (following Placet 1658) argued, that the Atlantic Ocean was essentially a huge river valley, the sides of which had become separated by a great volume of water across which Noah's ark had sailed (cf. Wegener 1915). Von Humboldt, however, was also one of the traveller-naturalists of the 18th and 19th centuries, who gradually undermined the paradigm. The increasing knowledge of distribution and classification of plants and animals, both living and fossil, accumulated evidence for continuous and gradual change, for evolution. At the revolutionary end of the 18th century, God had become a 'superfluous hypothesis' in science (Laplace), and diluvial theory started to give way.

Especially the palaeontological evidence of repeated mass extinctions had begun to strain belief in a benign creator. Noah's flood could not account anymore for the necessary series of cataclysmic events. The supranatural explanation was abandoned and catastrophism lost its respectability, not to be restored until extra-terrestrial causes for mass extinctions were (re)introduced by Alvarez et al. (1980) and Smit & Hertogen (1980).

In 1795 Hutton presented the hypothesis that glacier ice had been the agent of transportation of erratic boulders in the Jura Mountains. Lyell in 1830–1833 refined the theory of uniformitarianism in showing that past change may result from slow and steady accumulation of ordinary small changes over vast periods. Although the view that glaciers had extended beyond their present positions, gradually became wider known (Agassiz 1837), it took until the 1860s that glacial theory was widely accepted. In 1863 Archibald Geiki suggested multiple glaciation, several cold stages or glacials alternating with warm stages or interglacials. This concept was further substantiated by his younger brother James Geiki in 1874. At the same time other important glaciation-related discoveries were made. Jamieson (1865) presented evidence for changing sea-levels, based on observations from Scotland, Scandinavia and North America. In 1882 Von Richthofen launched the idea of aeolic origin of löss deposits (cf. Kukla 1977), while Penck & Brückner (1901–1909) described Danube terrace sequences and glacial moraines as resulting from four glacial stages, separated by warm interglacial intervals.

With the dawning of the glaciation concept, also ideas on the underlying causes were developed. Already in 1842 the French mathematician Adhémar had proposed that changes in the orbit of the earth could be responsible for climate change. At first in 1864, and later in 1875, the Scottish geologist Croll suggested that changes in the earth's orbital eccentricity could be the cause of ice ages. The absence of reliable dating techniques, however, made it impossible to check astronomic predictions with geological observations. As a consequence, Croll's theories fell into disuse until they were resurrected by the Servian astronomer and physicist Milankovitch (1920, 1941). Milankovitch's theories, although already popular in the 1920s (e.g. Köppen & Wegener 1924, Brooks 1926, Walter 1927), were only widely accepted when data from temporally-long, deep-ocean, ice, löss, lake and peat sequences became available (Hays et al. 1976, Johnson et al. 1972, Kukla 1987, Hooghiemstra 1984).

In the meantime, also other causal theories were launched. In 1909 Arrhenius presented the theory that glacial–interglacial cycles were caused by changing CO_2 concentrations in the atmosphere (cf. Hansen et al. 1981, Berger & Killingley 1982), influenced by volcanic eruptions (cf. Bray 1976, Ninkovitch 1976). Ramsay (1910) and Sandström (1924) pointed at changes in atmospheric circulation as a result of orogeny (cf. Ruddiman & McIntyre 1981). Other 'old' theories included the lowering of the global sealevel and a consequent drop of the snowline over large parts of the earth (Enquist 1915), changes in oceanic circulation (cf. Van der Vlerk & Florschütz 1950, Broecker et al. 1985), changing positions of the earth's rotation axis (Hann 1883, Köppen & Wegener 1924), periodic changes inside the earth (Holmes 1925, 1926, Joly 1928), and changes in solar radiation (Dubois 1893, Nölke 1909, cf. Eddy 1977). In 1926 the Englishman Brooks postulated the positive feedback effect of an ice sheet (cf. Weyl 1968, Oerlemans 1980, Denton & Hughes 1983).

The chief importance of geological uniformitarianism was the vastly greater time scale it offered. Within that framework, both biogeography and palaeontology could contribute substantially to the knowledge of ecological, and related climatic change. Already Gmelin (1747) had noticed the disjunct distribution of arctic-alpine plants. Darwin (1859) used the concept of glaciation to explain this disjunction and postulated: 'By the time that the cold had reached its maximum, we should have a uniform arctic fauna and flora, covering the central parts of Europe.' Palaeobotanic proof of this supposition was soon to follow.

In 1842 Steenstrup had concluded from botanical macro-remains in Danish Holocene peats that the climate must have been colder in the past. In 1870 Nathorst actually discovered macrofossils of arctic plants in the Late Glacial lake clays of Scania (South Sweden) and deduced the former presence of a tundra vegetation. These clays were characterized by the predominance of leaves of *Dryas octopetala* and *Salix polaris*. In the following years many fossil remains of arctic plants were found, enabling Nathorst (1891) to present an overview on the distribution of glacial flora, the so-called 'Dryas-flora', in Sweden, Denmark, Germany, Switzerland, Russia and England. In the sediments a consistent stratigraphical pattern was observable: peat on top, covering gyttja, lake marl, clay and sand. The 'Dryas-flora' was especially found in clay layers, rarely in peat or gyttja. Scrupulous analysis of Neuweiler (1901) showed that no tree pollen was present in the Dryas clays, indicating a complete absence of forests and trees. In 1926 a fossil Dryas flora was first encountered in the Netherlands at the transition of lake marl and clay in sediments near Winterswijk (Florschütz 1927)

In 1901 Hartz & Milthers discovered that Late Glacial warming had not been a gradual and continuous proces. In a lake basin at Allerød (Denmark) they found laminated upper and lower clays, containing soliflucted pebbles, which were separated by an organic mud. The mud contained remains of birches, while arctic-alpine species were dominant in the clays. The sequence was interpreted as representing two cold phases separated by a temperate period. A similar phenomenon was found in mires in Scotland and northern England, where between two forest beds, the lower always consisting of the remains of birch, 'arctic-alpine plants are found ... in a layer which is unusually sharply marked by its abundance in *Empetrum* stems' (Lewis 1905, Samuelsson 1910). In 1904 Schröter, in collaboration with Brückner, noted that the fossil Dryas flora was specifically associated with the last readvance of the glaciers in the Swiss Alpenvorland (Früh & Schröter 1904).

Similar macrofossil sequences in peat deposits induced Blytt (1876) and Sernander (1894), both Scandinavian geologists, to originate a stratigraphical scheme for Late Glacial and Holocene vegetation history in northwest Europe and associated climatic changes. This scheme, including the Arctic, Subarctic, Boreal, Atlantic, Subboreal and Subatlantic periods, was related to a series of pollen zones by Von Post. Von Post (1916/1918) wrote in 'Skogsträdpollen i sydsvenska torvmosselagerföljder', the founding paper of Quaternary palynology: 'The rapid appearance of southern plants simultaneous with, or almost immediately following the disappearance of the Dryas-flora, must be considered a phyto-geographical anomaly unless it is explained as resulting from a very fast improvement of climate'. He proposed (1909) to call this 'the late-glacial (or better 'finiglacial') climatic improvement'.

The biological evidence for rapid climatic change in the Late Glacial was greatly strengthened by the application of pollen analysis, especially since the extension of the recognition of pollen of many herbaceous plants. In 1935 Jessen presented a new subdivision of the Late Glacial including Older Dryas time, Allerød oscillation and Late (= Younger) Dryas time. After the discovery of another smaller interstadial prior to the Allerød at Bølling-Sø, Iversen (1947) subdivided the Older Dryas time in Earliest Dryas time, Bølling oscillation and Earlier Dryas time. Some years later Waterbolk (1948, Bolleveen) and Van der Hammen (1949, Hijkermeer) proved palynologically the existence of Allerød and Younger Dryas in the Netherlands.

Although final causes have not been revealed yet, our knowledge of the Younger Dryas event has rapidly increased, and many new fields of research have been uncovered. Recent research results describe date and rate of the termination of the Younger Dryas in an increasingly detailed way. Soon a precision may be reached that approximates the old historical record of a similar event...: 'In the year when Noah was six hundred years old, on the seventeenth day of the second month, that very day all the springs of the great deep burst out, the windows of heaven were opened, and rain fell on the earth for forty days and forty nights.' (Genesis 7.10–7.12).

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