Most of the wood is from Tertiary sediments under basalt flows, or has been secondarily exposed. (MP849) (MP846, MP847 and MP848)

Tertiary and Quaternary fossil wood from Kerguelen (southern Indian Ocean)
Contes Rendus Acadamie de Sciences, Sciences de la terre et des planets 1998, 326, 901-906.

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Abstract : Kerguelen is now treeless but forest grew there during the Tertiary. Tertiary fossil wood is common there and was recorded and described by 19th Century workers. Recently discovered wood from a Pleistocene moraine shows that trees persisted into the Quaternary. A xylological study helps clarify the history and palaeoecology of the woody vegetation on Kerguelen.

Tertiary fossil wood is common and widespread on the now treeless Kerguelen (Ross, 1847; Göppert, 1881; Crié, 1889; Edwards, 1921). Specimens have been assigned to *Cupressinoxylon antarcticum* Beust (Beust, 1884; Edwards, 1921), *Cupressoxylon kerguelense* Crié (Crié, 1889) and *Dadoxylon kerguelense* Seward (Seward, 1919; Edwards, 1921). Recently, Cretaceous wood referred to *Podocarpoxylon* has been found around 1000 km southeastward (Francis and Coffin, 1992). Records of '*Araucarites schleinitzi* et *hookeri*' (Göppert, 1881) are not supported by illustrations or diagrams. Albert de la Rüe (1931) and Seward and Conway (1934) also studied Tertiary palaeobotanical material from Kerguelen. A record of dicotyledonous wood is dubious (Edwards, 1921). This work confirms the Tertiary occurrence of Araucariaceae and presents the first evidence for Quaternary wood.

Materials, methods and geological setting:

A Tertiary specimen was silicified and was studied using geological thin sections. It came from sediments exposed beneath basalt, about 30 meters above sea level at Port-Matha (figure).

Three other specimens came from consolidated moraines along Rivière des Macaronis (figure). These moraines are considered to be Quaternary: they fill a valley cut into Miocene sediments and basalts of maximum age 8 Ma (Leyrit, 1992). Phonolithic extrusions in the area have a maximum age of 2 Ma (Giret, 1993). No trace of glacial magmatism has been observed, implying a non-glacial time for this vulcanism. Finally, the widespread glaciation which produced the moraines of Rivière des Macaronis is considered to be Quaternary (Nougier, 1970). The preservation, similar to latest Pliocene-Early Pleistocene wood from Antarctica described by Francis and Hill (1996), also supports a relatively young age. The cells walls are in the first stage of gelification, but the rays are resiniferous and more altered. Parts are permineralised with hyperblastic calcite, destroying most of the structure. The wood was immersed in glycerine for 48 hours, boiled in water for three hours, razor sectioned, immersed briefly in bleach, dehydrated in alcohol and washed in xylene then mounted in Canada Balsam. All material is stored in the Laboratoire de paléobotanique de l'université de Lyon-I.

Results :

Agathoxylon kerguelense (Crié) comb. nov. = *Cupressoxylon kerguelense* Crié, 1889 = *Dadoxylon kerguelense* Seward, 1919 - Tertiary specimen n° MP849. This is a fragment about 10 cm long from a trunk or branch more than 30 cm diameter (based on its ring curvature). The rings are prominent, of variable width but not exceeding 1 mm. The specimen is a tracheidoxyl. The tracheids mostly have uniseriate auracarian-type radial pitting and low rays**.** The cross fields are araucarioid, with two to six, randomly arranged, cupressoid bordered pits per field. MP849 should, therefore, be assigned to *Agathoxylon* Hartig (Philippe, 1993). It is identical to Crié's holotype for *Cupressoxylon kerguelense* (Rennes Université, Musée de Géologie, n° 115 000), and to Seward's figuration for *Dadoxylon kerguelense*. We propose to name this species *Agathoxylon kerguelense* (Seward, 1919) Philipe comb. nov.

Widdringtonioxylon antarcticum (Beust) comb. nov. = *Cupressinoxylon antarcticum* Beust, 1884 Quaternary specimens MP846, MP847 and MP848. These specimens are massive, up to two m long.

The ring curvature implies that the wood came from trunks > 60 cm diameter. MP846, MP847 and MP848 are xylologically similar.
The wood appears to be tracheidoxyls, with very narrow, marked growth rings. The mean ring width of 106 rings from MP846 is 0.61 mm (σ= 0.19 mm). This sequence did not include the juvenile sigmoid phase. The tracheids are narrow, often resin filled, and quadrangular in section, with uniseriate abietinean type radial pitting. The rays are uniseriate (rarely locally biseriate), resin filled, usually less than five cells in height, with smooth, narrow walls, sometimes with tracheids. There are no indentures. The cross-fields have one or two cupressoid bordered pits. The axial parenchyma is abundant, resinous, usually with smooth transverse walls.
The specimens assigned by Edwards (1921) to *Cupressinoxylon antarcticum* are identical to specimens MP846, MP847 and MP848. The form genera, *Widdringtonioxylon* Greguss 1967 and *Widdringtonoxylon* Penny 1947 can both be used for this wood (Vaudois & Privé, 1971). We assign MP846, MP847 and MP848 to *Widdringtonioxylon antarcticum* (Beust) Philipe *nov. comb*. This wood is quite consistent with *Widdringtonia* (Peirce, 1938). Kraüsel's (1949) suggested affinity with Podocarpaceae for Edwards' (1921) *C. antarcticum* is inconsistent with our observations as well as with Edwards' illustration.

Discussion :

Cupressaceae and Araucariaceae grew on Kerguelen in the Tertiary. These trees probably coexisted (e.g Seward and Conway 1934). Cupressaceous trees were present in the Quaternary. A species could have colonised Kerguelen in an interglacial or interstadial, but colonisation by a species with identical wood to one of the Tertiary forms seems very unlikely because Kerguelen is more than 3000 km from any large land mass. Thus, a Tertiary conifer apparently survived on Kerguelen through the climatic deterioration of the Latest Pliocene/Earliest Pleistocene, to become extinct by the Middle or Late Pleistocene. A similar pattern of extinction occurred in Tasmania (Macphail, *et al*., 1993; Jordan, 1995). Quaternary trees may have taken advantage of the period between 40 and 30 . 10^3 years (oxygen isotope stage 3, Gendron-Badou et al., 1997).

While the extant flora of Kerguelen has affinities with the fuegien region (Seward et Conway, 1934), there is a 'South African' element (*Widdringtonia*) in the Tertiary and Pleistocene floras. This is consistent with Wace's (1960) suggestions that the cold climate floras and faunas around Antarctica were mainly derived from western sources.

The Tertiary and Quaternary wood from Kerguelen has narrow and marked rings (e.g. Edwards [1921] gave a mean ring width of 0.5 mm), suggesting climates marginal to tree growth, probably due to proximity to a climatic tree line (Brockmann-Jerosch, 1928). In the temperate and subpolar Southern Hemiphere, tree height declines gradually approaching the treeline. Some of the Tertiary wood was from very large trees (up to 2 m in diameter), which is consistent with at least one or two hundred metres altitude below a climatic treeline. The Quaternary specimens have ring widths comparable to those from trees living in extreme environments, such as *Pinus longaeva* Bailey from White Mountains (Californie) or *Diselma archeri* from Tasmania. A somewhat warmer climate cannot be excluded because other extant conifers growing in much warmer conditions: e.g. *Lagarostrobos franklinii* from near sea level in Tasmania (1000m below the tree line) and *Fitzroya cupressoides* from Chile have similar ring widths.

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