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Diatom analysis of a core from Ennerdale

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DIATOM ANALYSIS OF A CORE FROM ENNERDALE

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SUMMARY

Ten sediment samples from a core obtained from Ennerdale, English Lake District, were analysed for percentage diatom abundance and total diatom concentration. pH reconstruction suggests a drop of about half a pH unit from *c.* pH 6.7 at the base of the core to *c.* pH 6.3 at the top of the core.

METHODS

Sediment samples from 0,1,2,3,4,8,12,16, 20 and 40 cm were prepared for diatom analysis by oxidation with hydrogen peroxide using standard methods [1]. Absolute concentrations were obtained by adding a known quantity of calibrated microspheres to a weighed sediment sample [2]. A total of at least 500 valves were counted from each slide under oil immersion at x1000 magnification, using phase contrast microscopy. Diatom taxonomy followed the Surface Waters Acidification Programme (SWAP) guidelines [3]. The diatom data has been archived on the Environmental Change Research Centre database, AMPHORA, and is presented graphically using TILIAGRAPH [4].

pH was reconstructed from the SWAP surface sediment data set [3] [5] using the weighted averaged partial least squared (WAPLS- 2 component) method, implemented by the CALIBRATE software [6].

RESULTS

The 10 samples contained a diverse range of species with 119 taxa found, only 23 of these were found at an abundance of greater than 1% (Figure 1). A full species list with authorities is given in Appendix 1 and rare species are shown in Figure 2.

The base of the core (40 cm) is dominated by the centric, planktonic species *Cyclotella kuetzingiana* which make up over 60% of the assemblage (Figure 1). Other important taxa are the benthic species *Brachysira vitrea and Achnanthes minutissima*, with small amounts of other benthic species such *as Brachysira brebissonii*, *Tabellaria flocculosa*, *Cymbella lunata*, *Synedra tenera*, *Cymbella microcephala*, *Fragilaria vaucheriae* and *Diatoma hyemale*. This assemblage appears to be stable and persists to around 12 cm (*c.* 1907 AD)

Above 12 cm (*c.* 1907 AD) changes in the diatom assemblage start to take place, the most obvious being the loss of the planktonic *Cyclotella* which continues to decrease in abundance to 1cm (*c.* 1984 AD), appearing to stabilise at the top of the core. A few species such as *Cymbella microcephala* and *Synedra tenera* also decline. The loss of *Cyclotella* is compensated for by the increase in the abundance of *B. vitrea* and *A. minutissima* and of several other benthic taxa for example; *Achnanthes marginulata*, *Achnanthes scotica, Fragilaria virescens* v. *exigua*, and *Peronia fibula*. Diatom concentrations are high and show a trend to lower values from bottom to top.

The results of pH reconstruction (Figure 1, Table 1) show a trend of decreasing pH with the most rapid change occurring between 8 cm (*c.* 1944 AD) and 4 cm (*c.* 1969 AD). However, the magnitude of change is rather small, about half of a pH unit.

Table 1 WAPLS (2 component) pH reconstruction for the core

Depth (cm)	0	1	2	3	4	8	12	16	20	40
Date AD	1988	1984	1979	1974	1969	1944	1907	1866		
WAPLS	6.28	6.30	6.24	6.50	6.53	6.69	6.71	6.78	6.78	6.70

DISCUSSION

The loss of a *Cyclotella* plankton is a common phenomena in many lakes in the U.K. It is often seem as one of the earliest stages in lake acidification, as these taxa appear to be very sensitive to acid deposition. The loss of *Cyclotella* commonly occurs at unafforested sites in the UK. For example at Loch Tinker in the Trossachs, a decline in *Cyclotella* was found to be associated with other evidence for mid-19th century atmospheric contamination [7]. At Ennerdale the start of acidification appears to be later than at many sites in the UK; with the major changes occurring after the start of the 20th century.

At many sites *Cyclotella* taxa are replaced by acidophilous species with lower pH preferences, however at Ennerdale the main taxa which replace the *Cyclotella* are circumneutral taxa with rather similar pH optima. Some taxa such as *A. scotica*, and *F. virescens* v. *exigua* with lower optima increase slightly but their increases are low and consequently there is only a small decline in reconstructed pH.

At afforested sites it has been suggested that the loss of a *Cyclotella* plankton may occur as a result of disturbance through ploughing and soil erosion. However, at this site it appears that sediment accumulation rates have not changed significantly during the past *c.* 120 years [8] and therefore there is little direct evidence for extensive disturbance. The early 20th century loss of *Cyclotella* (beginning at *c.* 1907 AD) is also not compatible with the start of afforestation in 1927 which was completed by 1950. In addition only about 20-25% of the catchment is planted, so forestry may not have had as big an effect as elsewhere (Ed Tipping *pers. comm.*).

The discrepancy between the reconstructed pH at the top of the core (pH 6.3) and the current mean measured pH of 6.5 (Ed Tipping *pers. comm.*) may be partly due the loss of 2 cm (representing the last *c.* 10 years) of material from the top of the core [8].

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Acidification Programme (SWAP) calibration set. Journal of Paleolimnology, In press.
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8. Tanbay, A., *Report on the radiometric dating of a sediment core from Ennerdale*, . 1999, University of Liverpool.

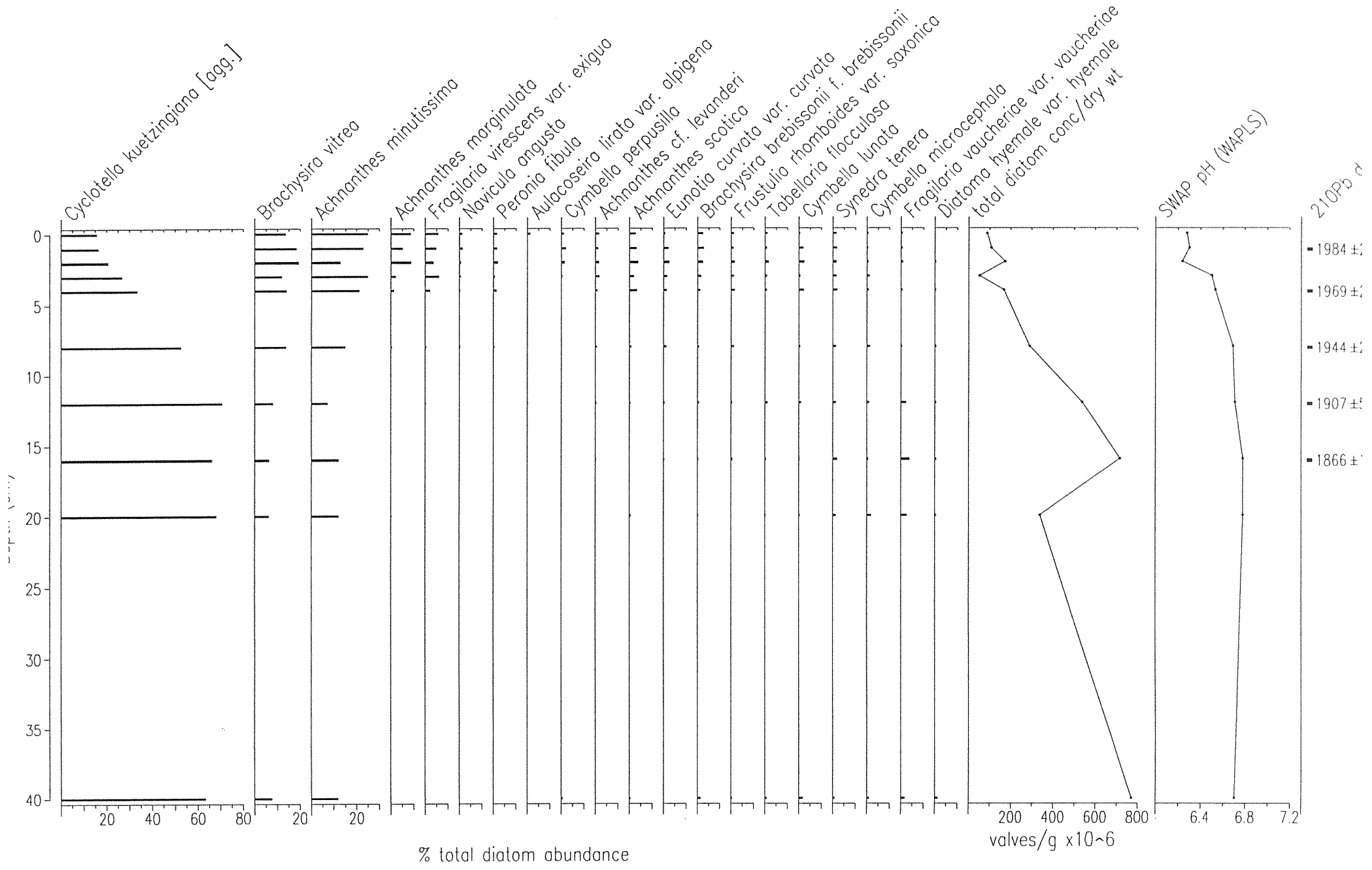
APPENDIX 1 FULL LIST OF DIATOM SPECIES

Achnanthes minutissima minutissima Kutz. 1833
Achnanthes austriaca helvetica Hust. 1933
Achnanthes marginulata Grun. in Cleve & Grun. 1880
Achnanthes detha
Achnanthes lanceolata (Breb. ex Kutz.) Grun. in Cleve & Grun. 1880
Achnanthes altaica (Poretzky) A. Cleve-Euler 1953
Achnanthes kuelbsii Lange-Bertalot 1989
Achnanthes scotica Jones & Flower
Achnanthes flexella (Kutz.) Brun 1880
Achnanthes cf. *levanderi*
Achnanthes austriaca austriaca Hust. 1922
Achnanthes nodosa A. Cleve-Euler 1900
Achnanthes [altaica var. minor] L. Grannoch (RJF) 1988
Achnanthes linearis (W. Sm.) Grun. in Cleve & Grun. 1880
Achnanthes pseudoswazi J.R. Carter 1963
Achnanthes suchlandtii Hust. 1933
Achnanthes [marginulata] major Uaine (VJJ) 1988
Achnanthes sp.
Amphora ovalis pediculus (Kutz.) Van Heurck 1885
Asterionella formosa formosa Hassall 1850
Aulacoseira lirata alpigena (Grun.) Haworth
Aulacoseira distans tenella (Nygaard) R. Ross in Hartley 1986
Aulacoseira sp.
Brachysira vitrea (Grun.) R. Ross in Hartley 1986
Brachysira brebissonii brebissonii R. Ross in Hartley 1986
Brachysira styriaca (Grun. in Van Heurck) R. Ross in Hartley 1986
Caloneis sp.
Cymbella microcephala microcephala Grun. in Van Heurck 1880
Cymbella perpusilla A. Cleve 1895
Cymbella aequalis W. Sm. ex Grev. 1855
Cymbella cesatii cesatii (Rabenh.) Grun. in A. Schmidt 1881
Cymbella descripta (Hust.) Krammer & Lange-Bertalot 1985
Cymbella minuta minuta Hilse ex Rabenh. 1862
Cymbella minuta silesiaca (Bleisch ex Rabenh.) Reimer in Patr. & Reimer 1975
Cymbella lunata W. Sm. in Grev. 1855
Cymbella naviculiformis Auersw. ex Heib. 1863
Cymbella cymbiformis cymbiformis Ag. 1830
Cymbella sp.
Cocconeis placentula placentula Ehrenb. 1838
Cyclotella kuetzingiana agg.
Cyclotella radiosa (Grunow) Lemmerman 1900
Cyclotella schumannii (Grunow) Hakansson 1990
Cyclotella sp.
Diatoma hyemale hyemale (Roth) Heib. 1863
Diatoma hyemale mesodon (Ehrenb.) Kirchner 1878
Diatoma tenue elongatum Lyngb. 1819
Eunotia tenella (Grun. in Van Heurck) A. Cleve 1895

Eunotia exigua exigua (Breb. ex Kutz.) Rabenh. 1864
Eunotia incisa W. Sm. ex Greg. 1854
Eunotia naegelii Migula 1907
Eunotia curvata curvata (Kutz.) Lagerst. 1884
Eunotia exgracilis A. Berg ex A. Cleve-Euler 1953
Eunotia pectinalis pectinalis (O.F. Mull.) Rabenh. 1864
Eunotia exigua tridentula
Eunotia praerupta-nana Berg
Eunotia pectinalis minor (Kutz.) Rabenh. 1864
Eunotia flexuosa flexuosa Kutz. 1849
Eunotia paludosa Grun. 1862
Eunotia tridentula Ehrenb. 1843
Eunotia [sp. 12 (minor)] L. Grannoch (RJF) 1988
Eunotia sp.
Fragilaria virescens exigua Grun. in Van Heurck 1881
Fragilaria vaucheriae vaucheriae (Kutz.) J.B. Petersen 1938
Fragilaria construens venter (Ehrenb.) Grun. in Van Heurck 1881
Fragilaria sp.
Frustulia rhomboides saxonica (Rabenh.) De Toni 1891
Frustulia rhomboides viridula (Breb. ex Kutz.) Cleve 1894
Gomphonema angustatum angustatum (Kutz.) Rabenh. 1864
Gomphonema hebridense Gregory 1854
Gomphonema parvulum parvulum (Kutz.) Kutz. 1849
Gomphonema sp.
Gomphonema gracile Ehrenb. 1838
Hannaea arcus arcus (Ehrenb.) Patr. in Patr. & Reimer 1966
Krasskella kriegerana (Krasske) R. Ross & Sims 1978
Navicula radiosa tenella (Breb. ex Kutz.) Grun. ex Van Heurck 1885
Navicula angusta Grun. 1860
Navicula bremensis Hust. 1957
Navicula schassmannii Hust. 1937
Navicula seminulum Grun. 1860
Navicula impexa Hust. 1961
Navicula tenuicephala Hust. 1942
Navicula leptostriata Jorgensen 1948
Navicula radiosa radiosa Kutz. 1844
Navicula subtilissima Cleve 1891
Navicula mediocris Krasske 1932
Navicula minima minima Grun. in Van Heurck 1880
Navicula contenta contenta Grun. in Van Heurck 1885
Navicula cocconeiformis cocconeiformis Greg. ex Greville 1855
Navicula bryophila bryophila J.B. Petersen 1928
Navicula sp.
Neidium alpinum Hust. 1943
Nitzschia perminuta (Grun. in Van Heurck) M. Perag. 1903
Nitzschia fonticola Grun. in Van Heurck 1881
Nitzschia frustulum (Kutz.) Grun. in Cleve & Grun. 1880
Nitzschia angustata angustata (W. Sm.) Grun. in Cleve & Grun. 1880
Nitzschia sp.

Peronia fibula (Breb. ex Kutz.) R. Ross 1956
Pinnularia viridis viridis (Nitzsch) Ehrenb. 1843
Pinnularia microstauron microstauron (Ehrenb.) Cleve 1891
Pinnularia appendiculata (Ag.) Cleve 1896
Pinnularia subcapitata subcapitata Greg. 1856
Pinnularia subcapitata hilseana (Janisch ex Rabenh.) O. Mull. 1898
Pinnularia irrorata (Grun. in Van Heurck) Hust. 1939
Pinnularia sp.
Rhizosolenia sp.
Stauroneis anceps gracilis Rabenh. 1864
Stauroneis phoenicenteron phoenicenteron (Nitzsch) Ehrenb. 1943
Stenopterobia sigmatella (Greg.) R. Ross in Hartley 1986
Surirella delicatissima delicatissima Lewis 1864
Surirella biseriata biseriata Breb. & Godey 1835
Surirella sp.
Synedra tenera W. Sm. 1856
Synedra sp.
Tabellaria flocculosa flocculosa (Roth) Kutz. 1844
Tabellaria flocculosa agg.
Plankton
Unknown naviculaceae
Unknown

gure 1 Ennerdale Summary Diagram



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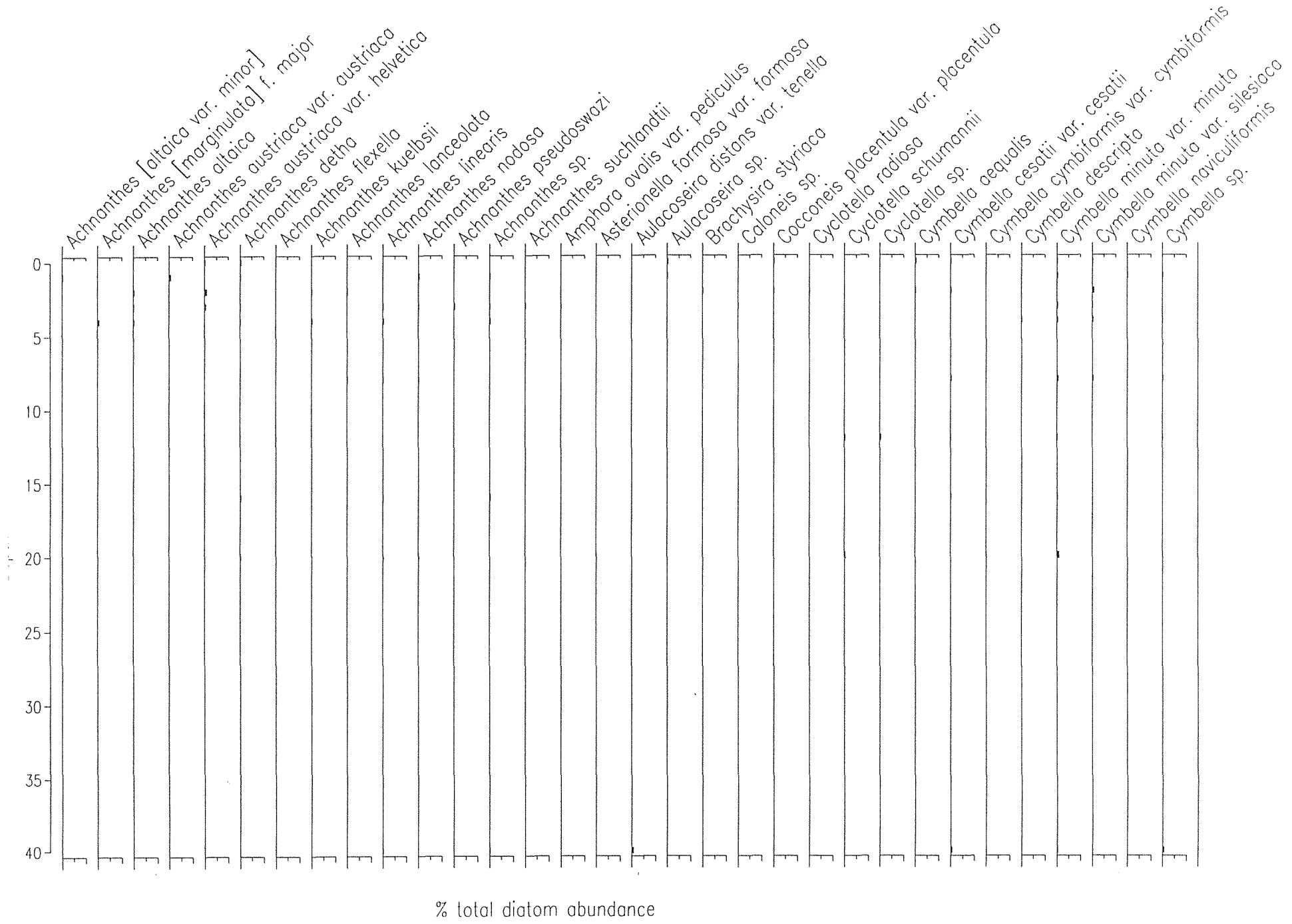

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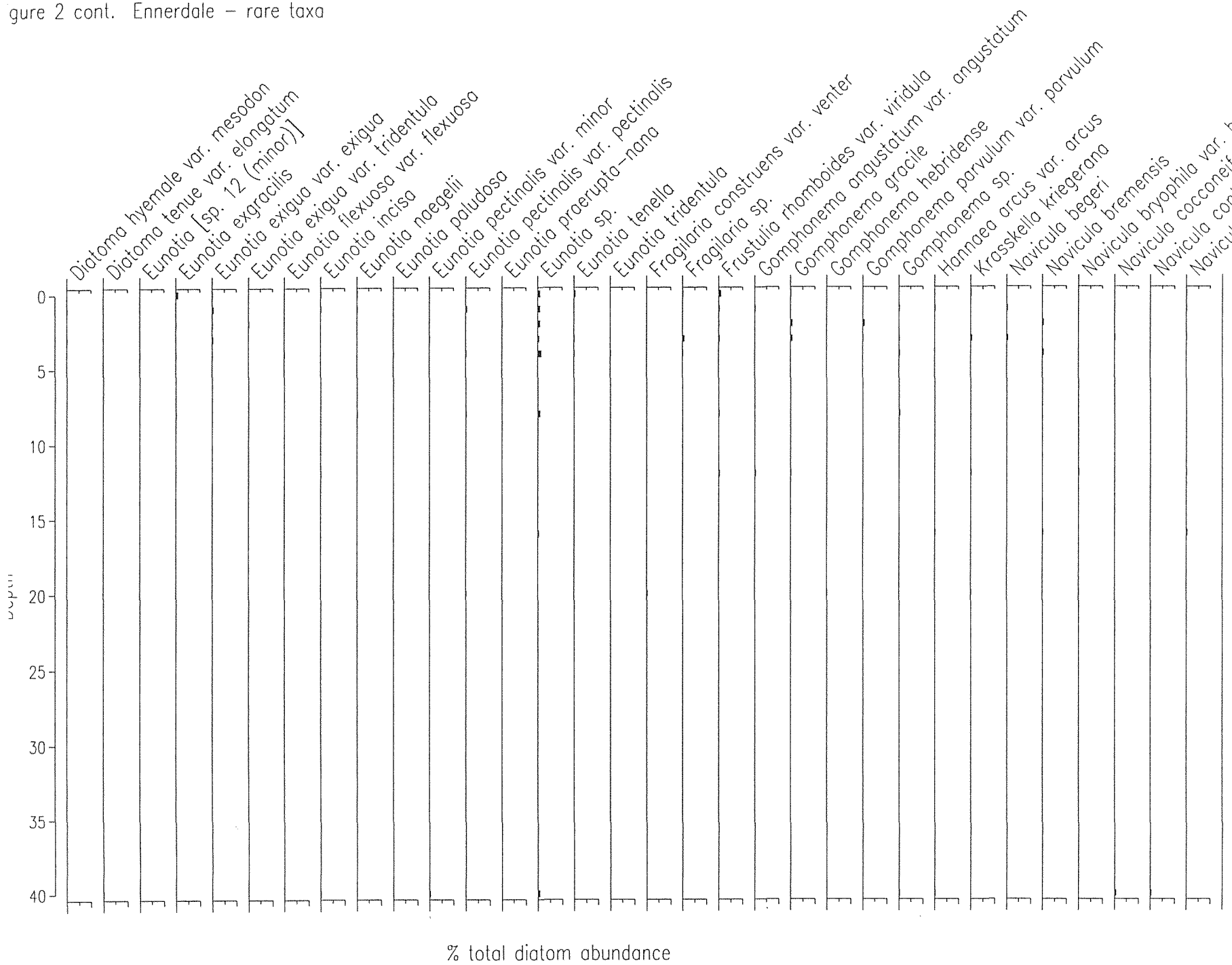

gure 2 cont. Ennerdale – rare taxa