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An expanded modern dinoflagellate cyst dataset for the Southwest Pacific and Southern Hemisphere with environmental associations

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ABSTRACT

Organic-walled dinoflagellate cyst (dinocyst) assemblages were examined in 120 sea floor sediment samples from the Southwest (SW) Pacific to highlight dinocyst distribution in the region. From these 120 samples, census counts of 40 samples were added to previously published census data from the Southern Hemisphere to form a modern dataset of 311 samples (SH-311). Cluster analysis (*k*-means clustering) of a 98-sample subset from the SW Pacific (NZ-98) reveals four distinct assemblages which coincide with modern Subantarctic surface water, the Subtropical Front and two clusters from Subtropical surface water. A similar clustering of the SH-311 dataset reveals an additional three assemblages, two associated with Polar waters colder than those sampled in the SW Pacific, and one that may be endemic to the South Atlantic Ocean. Multivariate ordination (canonical correspondence analysis and redundancy analysis) indicates that the dinocyst assemblages change most along a sea surface temperature (SST) gradient, in both the regional SW Pacific and Southern Hemisphere datasets. SST accounts for 38% to 56% of the species–environmental relationship after removal of covarying variables, and contributes 2–3 times the explainable inertia than the other environmental variables tested. Both modern datasets (SH-311 and NZ-98) are suitable as a training set for quantitative palaeotemperature transfer functions applied to Late Quaternary records, with the caveat that the modern assemblage also displays sensitivity to productivity, shoreline proximity, bottom water oxygen, and water mass; variation that may be exploited in certain situations.

1. Introduction

Dinoflagellates are unicellular planktonic protists (Fensome et al., 1996). A small proportion of dinoflagellate species (about 10–20%) produce an organic-walled cyst that may be preserved in the fossil record (Dale, 1996). The composition of dinoflagellate cyst (dinocyst) assemblages in modern sediments has been shown to vary along various environmental gradients. Statistical ordination techniques applied to a global dataset of modern sea floor samples indicate that changes in relative composition of dinocyst assemblages are most pronounced along gradients of sea surface temperature (SST), nitrate, salinity, bottom water oxygen, and phosphate concentrations (Marret and Zonneveld, 2003; Zonneveld et al., 2013). The empirical relationships observed in modern sediments have been used to interpret Quaternary palaeoenvironmental conditions using fossil assemblages. These include semi-quantitative approaches (e.g., Esper et al., 2004; Verleye and Louwye, 2010a) or mathematical transfer functions that quantify environmental parameters such as SST, salinity, sea ice cover or productivity (e.g., Peyron and de Vernal, 2001; Marret et al., 2008; Bonnet et al., 2010).

Exploration of regional datasets reveals significant local exceptions to these global, latitudinal trends. The most common exception is faunal change along gradients of primary productivity (Radi and de Vernal, 2004, 2008; Marret et al., 2008; Pospelova et al., 2008; Verleye and Louwye, 2010b), sea-ice cover, and salinity (Rochon et al., 1999; de Vernal et al., 2001; Radi et al., 2001; Bonnet et al., 2012). The reports of regional variations at odds with global trends, combined with a degree of endemism in modern distributions apparently uncorrelated to major environmental gradients (Marret and Zonneveld, 2003; Verleye et al., 2011), strongly suggest that regional studies of modern dinocyst distributions are necessary prior to attempting palaeo-reconstructions from that region.

In the Southwest (SW) Pacific, the basis for a regional modern dinocyst dataset suitable for faunal transfer functions already exists (Marret and de Vernal, 1997; Marret et al., 2001; Crouch et al., 2010), building on earlier work documenting the diversity of assemblages in this region (McMinn, 1990, 1992; McMinn and Sun, 1994; Sun and McMinn, 1994). Further, the utility of fossil dinocysts for quantitative reconstruction of Late Quaternary sea surface conditions has been demonstrated in the region, where dinocyst assemblages

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examined from 125 ka to present at Deep Sea Drilling Project (DSDP) Site 594 were used to infer SST and salinity (Marret et al., 2001). That reconstruction of SST (and salinity, which largely covaries with SST) is largely supported by the results of an ordination of 38 sea floor samples from the east of New Zealand (Crouch et al., 2010), which found that SST was strongly correlated to assemblage changes. However, assemblage variation in Crouch et al. (2010) was also correlated with autumn chlorophyll-*a* concentrations, particularly in the vicinity of the Subtropical Front, a zone of regionally elevated primary productivity.

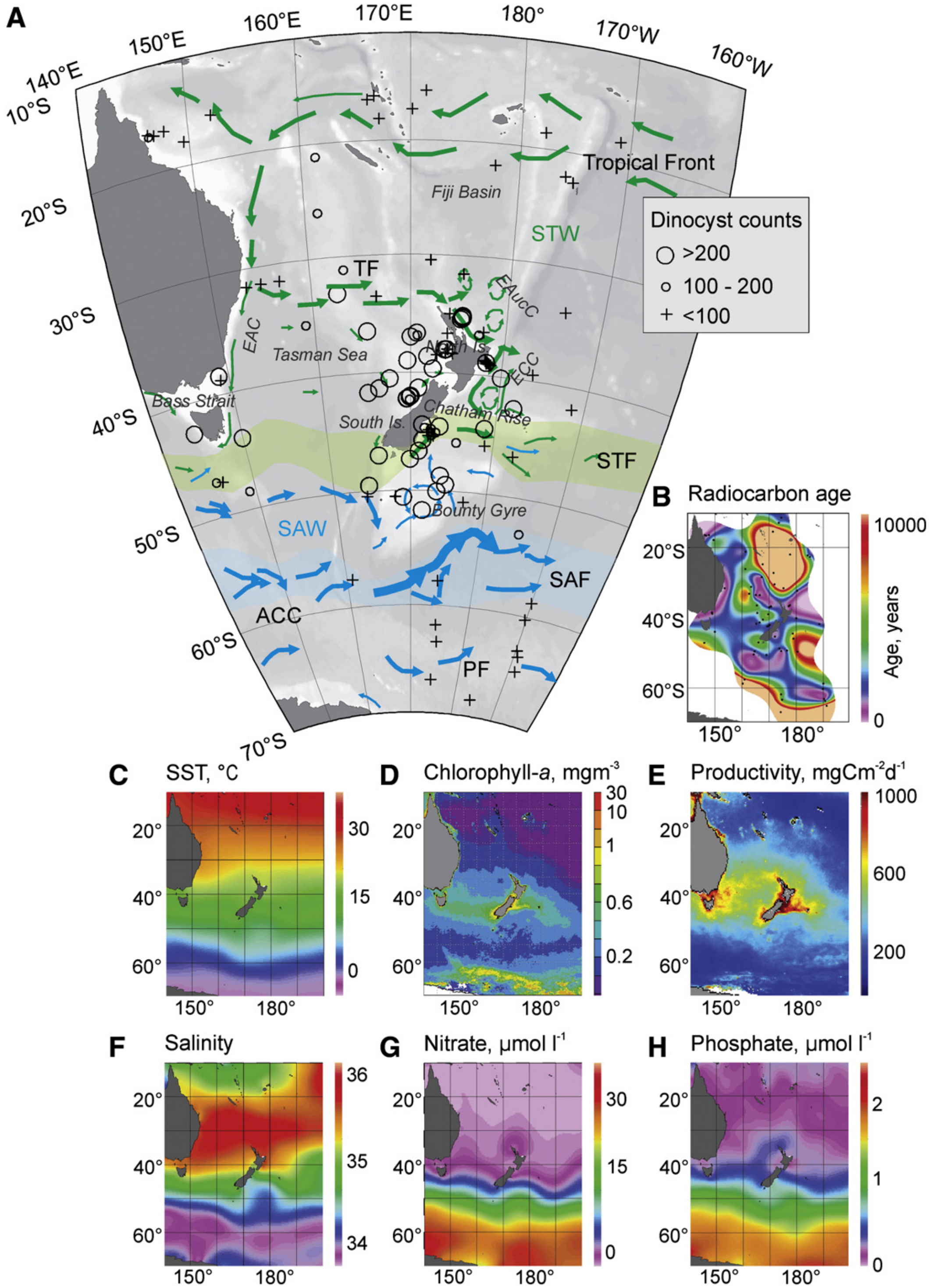

Fig. 1. A. Sea floor samples examined for dinocysts in this study (circles and crosses), along with significant surface oceanographic features mentioned in the text. EAC = East Australian Current, ECC = East Cape Current, EAucC = East Auckland Current, STW = Subtropical water, TF = Tasman Front, STF = Subtropical Front, SAW = Subantarctic water, SAF = Subantarctic Front, ACC = Antarctic Circumpolar Current, PF = Polar Front. Front locations are from Orsi et al. (1995) and Carter et al. (1998). B. Radiocarbon ^{14}C ages of 48 of the 120 sea floor samples examined in this study, contoured with DIVA-gridding from Ocean Data View (Schlitzer, 2011), sample locations shown by black dots. C Mean annual SST World Ocean Atlas 2009 1° climatology (Locarnini et al., 2010). D. Average satellite-derived chlorophyll-*a*, Jul 2002–Dec 2010 (MODIS-Aqua data, http://disc.sci.gsfc.nasa.gov/giovanni/, Acker and Leptoukh, 2007). E. Average satellite-derived productivity, Jan 2003 to Dec 2009 (MODIS and SeaWIFSs data, Behrenfeld and Falkowski, 1997). F. Mean annual sea surface salinity (World Ocean Atlas 2009 1° climatology, Antonov et al., 2010). G., H. Mean annual nitrate and phosphate (World Ocean Atlas 2009 1° climatology, Garcia et al., 2010a).