Globally-Extensive Deep-Time Ocean-Floor Sedimentary Data in Paleocoordinates

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Abstract

Ocean-floor drillsites, corings, and dredgings represent millions of years of earth and ocean history distributed along plate tectonic trajectories that may stretch over thousands of kilometers. To correctly locate the data in their context of climate zones and ocean-basin structure, they must be transformed to paleocoordinates along the trajectories, back from the drillsite. This poster describes software to do that transformation on large volumes of sediment, biological and chemical data, suitable for global-scale statistical data analysis.

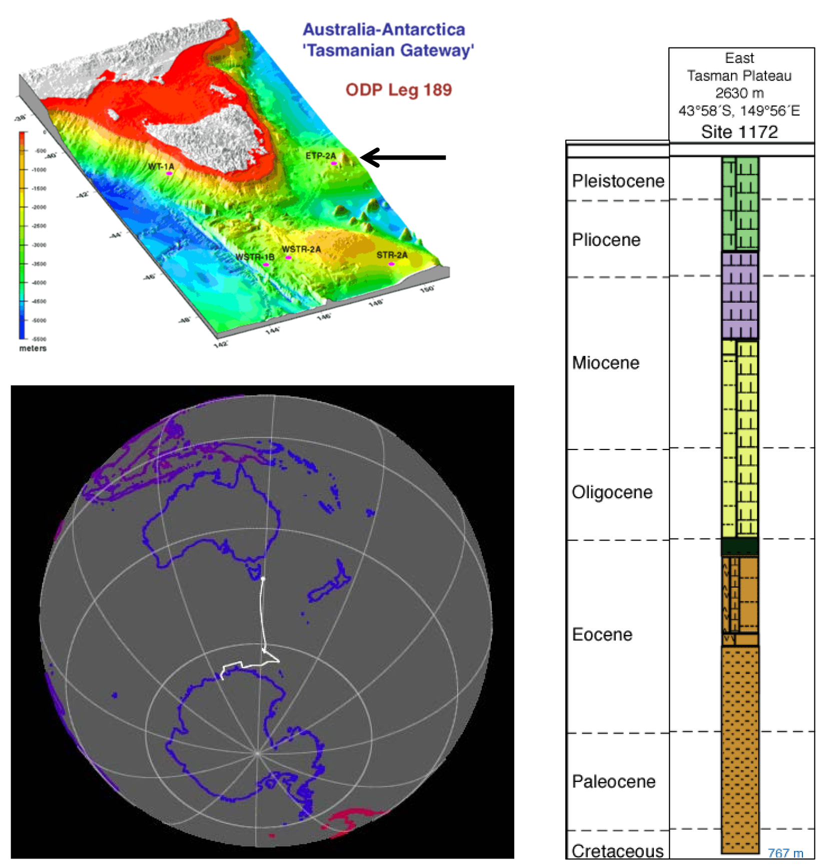

Fig. 1. Illustration of the issue of paleocoordinates for seafloor deep-time data. Data values in the Cretaceous-Recent data from ODP Hole 1172, East of Tasmania, is distributed along a trajectory that spans over 23° of latitude.

Introduction

There is a wealth of data on earth and ocean environments in the age-dated materials of the ocean drilling programs, and in corings and dredgings from many other expeditions. They are recorded at their sampling sites of course, but all the deep-time samples will have been conveyed by plate tectonic motions to that sampling site.

A new combination of software and data allows the such samples to be located to their paleo-locations – together with their analyzed sedimentary attributes and biologic components.

Having the data in paleocoordinates in this way – at their original detail, granularity and with parameter linkages - opens the possibility of large-scale statistical analysis of the sediments and biota through long periods of earth history. Finer scale phenomena such as ocean boundary currents and biogeochemical events will be better resolved. Quantitative assessments of uncertainty will be possible on conjectures about past conditions and events. And exceptional cases that may indicate something more interesting will stand out.

The marine records from cores, drillings, dredgings are sparse – but constantly being improved. More can be done to add industry data and word-based data. It will also be important to add continental platform data to the set. (Unfortunately deformed continental and oceanic tectonic zones present special problems, yet to be overcome.)

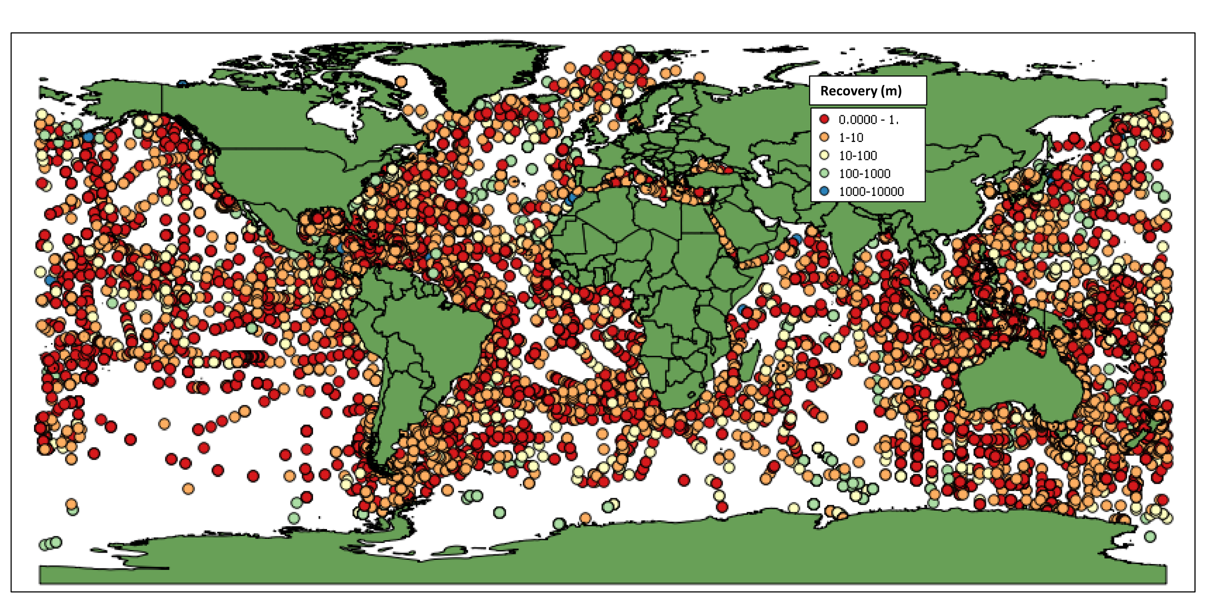

Fig. 2. Over 25,000 seafloor cores of >0.3m length are described in detail in dbSEABED, many with age-dating information.

Acknowledgements

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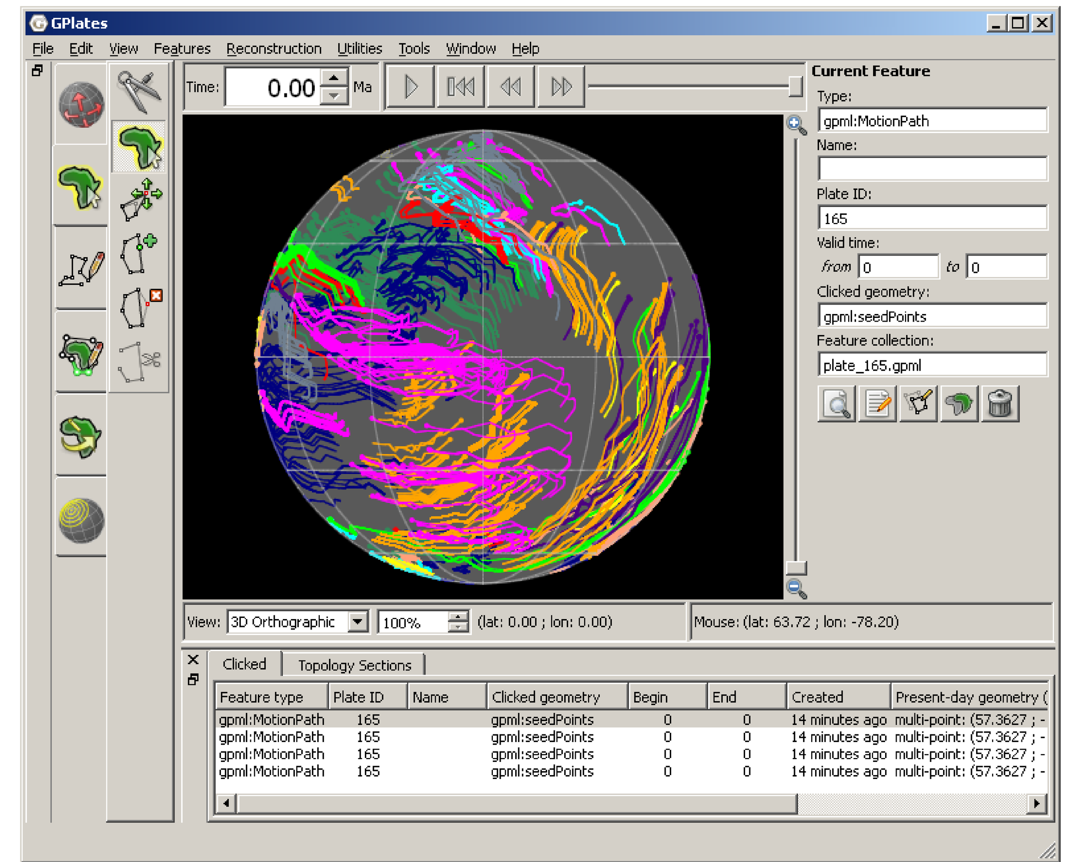


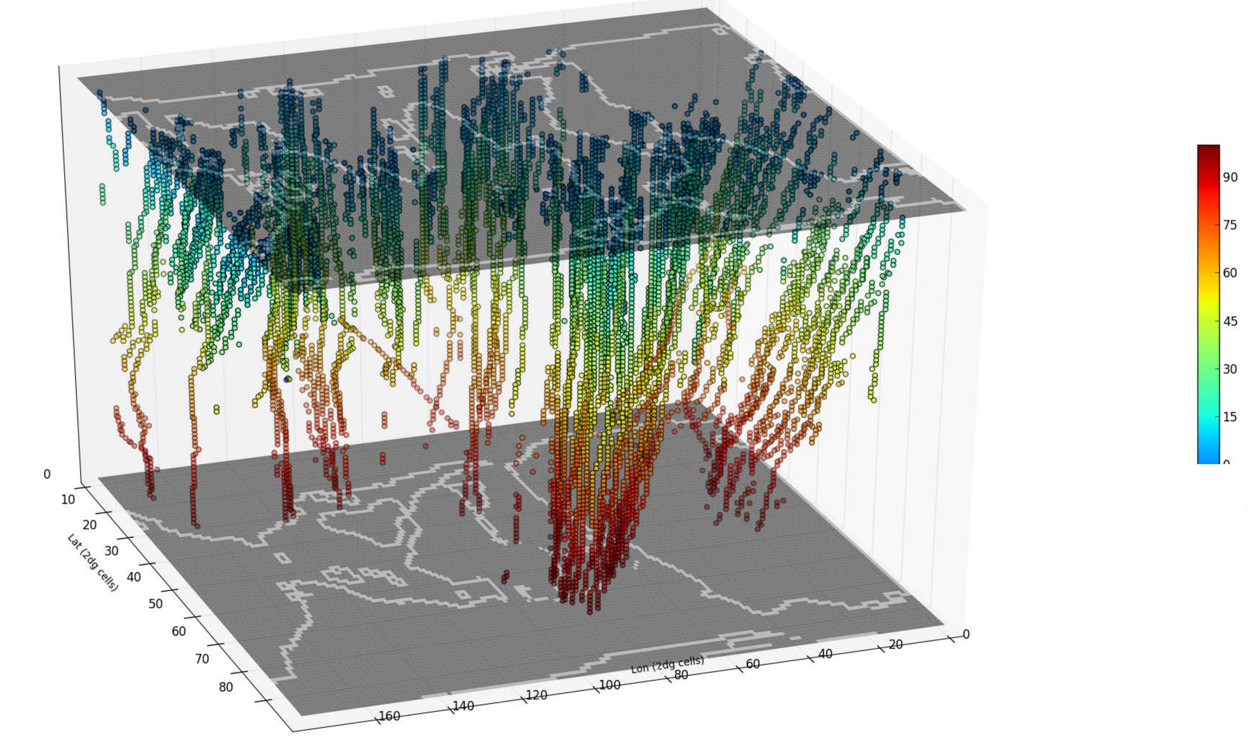
Fig. 3. Paleopaths of the dated deep-time samples, colored by their present day (drillsite) plate, all extending back for 140Ma. The GPlates software package (Boyden & others 2011) was used for reconstructions. A programmatic (e.g. Python) interface to Gplates programmatic rather than a manual interactive interfacing is recommended following this work.

Form of the Input Data

The form of the core sample data is a strong control on the necessary software methods.

- Scientific ocean drilling programs (DSDP, ODP, IODP) have now drilled over 1300 deep-penetration cores into the seabed globally, recovering lithologies of ocean-floor origin dated back to ~220Ma, Triassic (e.g., von Rad & others 1992). The drillings are somewhat biased to deep-ocean scenarios. Fortunately, they can be augmented using dated samples from short cores, dredgings and underwater outcrops (e.g., von Rad & others 1990). The current total in dbSEABED from all sources is 7,196 dated core, dredge, and drill sites.
- The basic sedimentary-lithologic data accompanying the datings indicate the geologic and environmental conditions at certain times and locations. This type of data is held in databases like dbSEABED and GeoMapApp (Goodwilli & others 2010). In the former the principal source is a 'top-20' set of parameters that address sediment textures and compositions, and also copious data on grain constituents. The total count of dated samples with geologic attributes is currently 1,033,783. The invaluable initial curation of these data was done by institutions such as NGDC, TAMU, and JAMSTEC, requiring very significant time and funding resources.
- It is important to recognize that, in many cases, later phenomena such as consolidation and diagenesis, tectonics and metamorphism will have been imposed at a subsequent time and location. Some parameters are strongly affected, especially physical properties.
- Application of age-models to the samples was essential for the ocean drilling datasets, but was severely limited by two factors. (i) The number of models is very limited. (ii) Considerable work was required to untangle non-standard sample namings (i.e., leg, site,hole, mbsf) in the various data sources (databases).
- Most age determinations have significant uncertainty which has several causes: the availability of age markers (like microfossils), analytical limitations, the breadth of biostratigraphic units, and crosswalk between biostratigraphy and absolute chronostratigraphy (Cohen & others 2013). In the current system, based on dbSEABED, an age is represented as youngest to oldest range with uncertainties quoted above these central values.

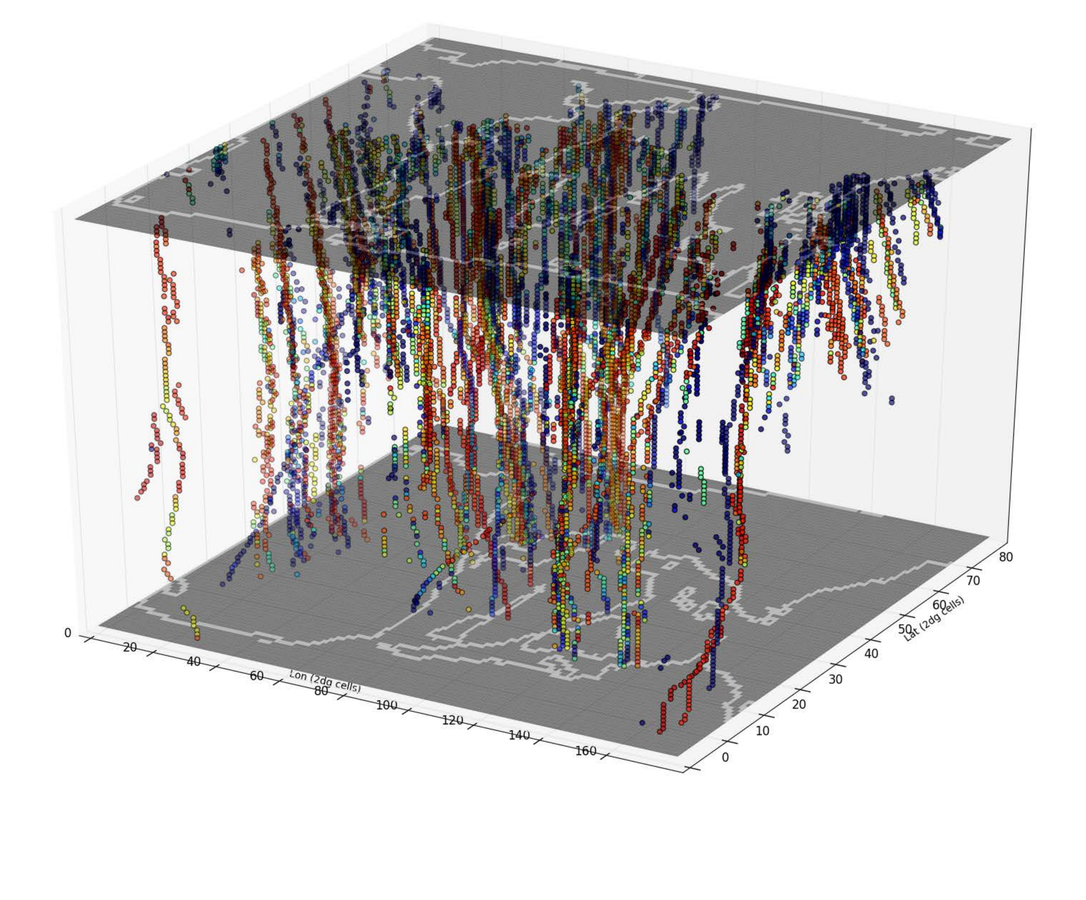
Fig. 4. Distribution of age-values for samples contributing to the datacube, colored from blue to red (0 to 100Ma). The top and lower panels show present-day and reconstructed 100Ma continental outlines.



The Processing Pipeline

- Aggregation of the sedimentary data within a unified and globally extensive database structure. For this project dbSEABED information processing system (Jenkins 1997; Goff & others 2008) performed the necessary harmonization of the formats, units and parameters, and integration of the word-based and numerical data types.
- Identification of the present-day plate based on the sampling location. Two mutually-checking methods were employed, based on the plate Static Geometries of Seton & others (2012): (i) spherical geometry point-in-polygon; (ii) raster plate depictions. An unresolved difficulty is the case of sites located in accretionary wedges at consuming plate margins.
- Submitting the collection site information to GPLATES in GPML format and computing the paleo-coordinate paths at 1my intervals, back to 100Ma. Site identification could not be carried through the GPLATES process. Positional matching between sampling sites and the reconstruction seed-points was therefore required.
- Assigning age dates to each sample, preserving their serial order in cores, and associating uncertainties. This is far from a trivial operation. Matching published age models (Cervato & others 2005) to data-based site-sample and lab-analysis names is a practical problem.
- Attach the computed paleocoordinates to the samples. Note that the standard reconstruction path output from GPLATES, in 1Ma steps, is coarse compared to the chronology of the Quaternary but finer than many age determinations older than Miocene.
- To visualize the results, paleogeographic basemaps were obtained from the 'AgeGrids' collection of Seton & others (2012). For this exploratory study the sediment attribute data (e.g., carbonate percent) were assigned to gridcells within an XYT 'datacube'. This is a good format for data dissemination. In the 2x2dg, 1Ma resolution 'cube' 2,694 cells currently have values.

Fig. 5. Carbonate values for Ocean Drilling and other cored sites, last 100Ma. The top and lower panels show present-day and reconstructed 100Ma continental outlines. The long blue track (LHS) began in SE Pacific, is now at the Peruvian subduction zone. The long red track (RHS) started in the Antarctic continental massif, is now at the Lord Howe Rise.



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