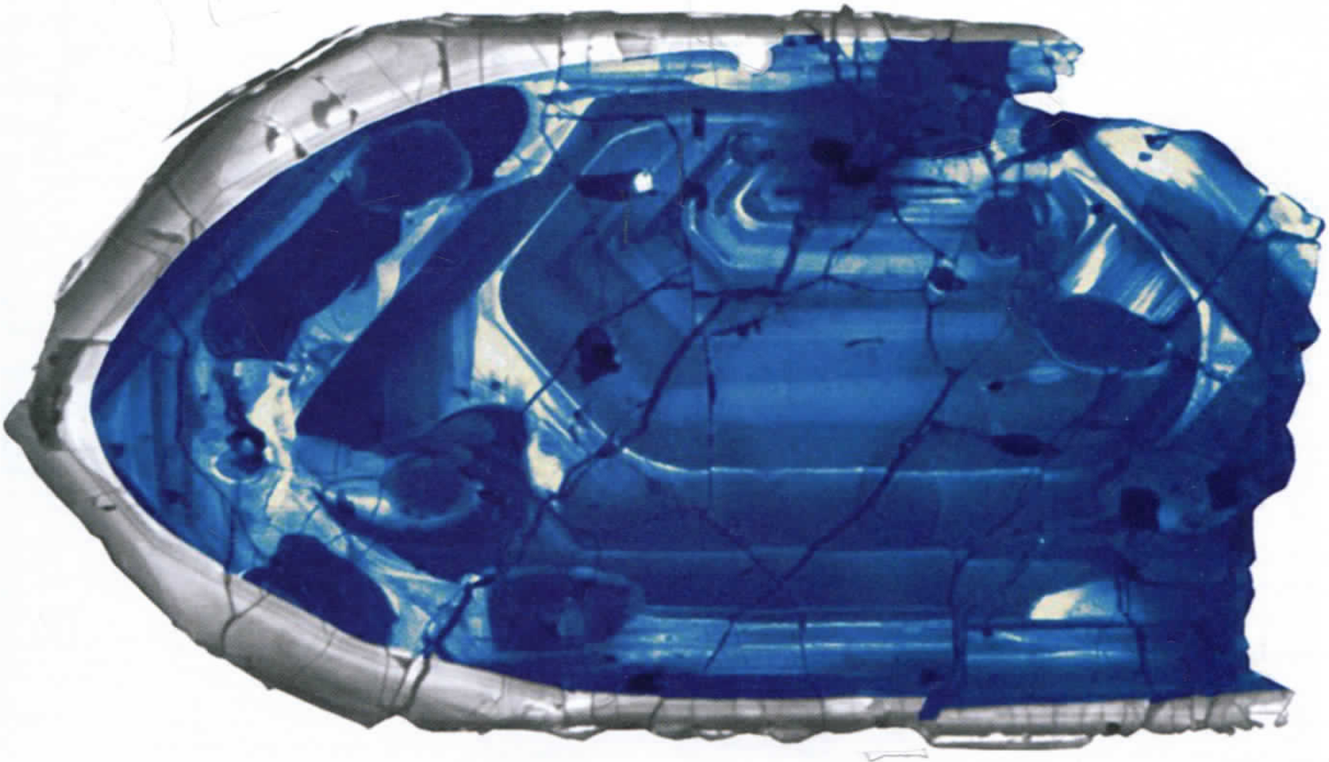
1 Introduction



The oldest known zircon on Earth is 4.374 $\pm$ 0.006 billion years old. This grain is from the Jack Hills in Western Australia and is about 200 million years younger than the age of the Earth, and is probably a remnant of the oldest continental crust. Credit: John Valley, University of Wisconsin/Nature Geoscience.

When the Earth is viewed from space on a cloudless day, all that can be seen are the edges of lands, seas, and ice caps, all of which can be objectively mapped. From further geophysical exploration, the identities and margins of the oceans and the continental lithosphere which lie beside and below them today can also be discovered. However, how and when all those margins have changed through geological time becomes progressively less easy to discover and also less objective, since an uncertain number of the plates and their included oceanic and continental lithosphere have disappeared by subduction into the Earth's interior. In addition, much of the lithosphere has been distorted through tectonic processes, in many places very heavily.

Our chief aim in writing this book is to interpret, decipher, and describe the complex history of our planet over the most recent half-billion years and the processes through which it has changed, and to compile maps of the distribution of the many tectonic plates through that time, and also show where the lands and seas were situated over that long period. As is usual with narration, we start at the beginning and carry on progressively through time as it elapsed, but the result of that natural sequence is to commence by discussing the periods over which we have the fewest quantitative constraints on Earth's old geography, and thus our geographical reconstructions gradually become more accurate as time continues up to the present day.

The periods into which geological time is divided are shown on the endpapers within this book's covers. The history of the Earth falls naturally into two very unequal divisions: the Precambrian, in which there are no fossils of use in determining the positions of the former continents, and which, including the origin of the planet, is only summarised here in Chapter 4. The Precambrian was followed by the Phanerozoic at 541 million years ago (Ma), and the latter started with the Palaeozoic, from which there is no old *in situ* ocean crust preserved, but this is when the biota was distributed in faunal and floral provinces which are very relevant in assessing oceanic separations in the absence of much useful geophysical data (apart from palaeomagnetism). The boundary between the Palaeozoic and the overlying Mesozoic to the present day was at 252 Ma, after which the ocean-floor magnetic stripes and other useful geophysical data become progressively more abundant and objective, but when the biota, although interesting in its evolutionary development, is again of no primary help in deciphering the palaeogeography. Thus there are separate chapters here for each of the main geological systemic periods from the Cambrian to the Quaternary (Chapters 5 to 15).

But what are the stepping stones, which cover many geological and geophysical disciplines, by which we can achieve our aims? After this brief introduction, in Chapter 2 we describe the varied and often independent methods that we have used to reconstruct old lands and seas. In Chapter 3 we list the 268 unit areas among the many making up our planet which are the ones we have used in the construction of our kinematic computer-generated palaeogeographical maps through time, with a very brief sketch of their geological constitutions. Each of those units, which vary in size from large continents to small terranes, can be downloaded digitally from www.earthdynamics.org/earthhistory, together with a digital rotation file and various other files, which can be used by anyone to make their own reconstructions with GPlates (www.gplates.org) for any area and at any given time for the past 540 million years, with no fees involved but acknowledgements requested.

Over the past billion years, our planet's climate has fluctuated wildly between hot and cold temperatures, some so extreme that any life has been scarcely possible. Thus, as well as mentioning those climates during the individual periods in Chapters 4 to 15, the final Chapter 16 brings together the many factors which affect and support the Earth's climate, and also describes how and why that climate has changed so much during the half-billion years and how it has come to be what it is today. Unfortunately, that deeper time perspective appears to be lacking in many modern-day climate scientists and politicians.

But underlying all that, our book and all of geological thinking depends on knowing how long ago each past event occurred. So that we can comprehend and evaluate the number of years over which the many changes of the Earth's surface and interior have taken place since its origin, and from that the rates of those changes, it is essential to know objectively the amount of time available for their progression. Thus a reliable primary geochronology is critical for underpinning our work.

Since the pioneer work by Arthur Holmes in the early twentieth century, rocks have been dated by radiometric methods, using a great variety of the longer-lived radiogenic isotopes, some of whose half-lives extend over billions of years (Torsvik & Cocks, 2012). The most useful elements have been found to be carbon for the most recent 30,000 years, and a variety of others, including argon–argon ($^{40}Ar/^{39}Ar$) and uranium–lead (U/Pb), for older rocks. All radiometric ages have errors calculated individually, which are given in the original papers, and most are published with dates including proportions within a million years, but, so that this text can flow relatively unimpeded, we have rounded all ages earlier than the Cenozoic (66 Ma) to the nearest one million years, and do not quote the published error ranges here. But, although lacking the objective numbers which have come from geochronology, in much of the Phanerozoic finer time divisions exist through the use of quickly evolving animals and plants from which biozones have been defined, and which have been used in the correlation of rocks. An example of the latter is graptolites in the Silurian, some of whose biozones are less than 100,000 years long, in contrast to the radiometric ages for that period, which are not accurate to within about one-third of a million years.

The overall time scale on which our work depends is inside the endpapers of this book, where the dates for the bases of the major time units are shown, most of which have now been standardised by the International Union of Geological Sciences (IUGS) Commission on Stratigraphy (Cohen et al., 2013).

It has been difficult to know how many references should best be cited. Many textbooks are frustrating in their relative lack, or sometimes even complete absence, of references, whilst research papers usually include at least one reference to support every fresh statement, and often far too many more, particularly to papers written by friends of the authors. This has led us to compromise, and we apologise both to current workers for the omission of precise citation of much invaluable work, and also to those earlier scientists on whose shoulders we all stand, particularly since we have tended to refer to summary articles in many places here, rather than to the many papers which underpin those works.