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Ophiolite Conundrums

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Abstract

Ophiolites are a significant puzzle to both uniformitarian and Flood geologists. Currently thought to represent sections of lower crust and upper mantle thrust onto the continents during subduction by a process known as "obduction," ophiolites are found around the planet. Uncertainties in uniformitarian explanations are multiplied by the distinct parameters of biblical history, and no Flood model has yet provided a comprehensive explanation.

Introduction

Ophiolites are fascinating, mysterious rocks. They are thought to be slices of oceanic crust and upper mantle that are not subducted but are detached from the subducting block and either thrust up over continental crust or thrust directly beneath continental crust (Dewey and Casey, 2013). They can be over 10 km in thickness, and although they rarely exhibit the complete sequence, an ideal ophiolite would progress upward from upper mantle peridotite to lower crustal gabbro, to upper-crustal sheeted dikes, to pillow basalt, and finally to sedimentary rocks (Figure 1). In many cases, ophiolite sequences are found without the upper crustal components of sheeted dikes and sedimentary rocks.

The greatest challenge ophiolites present to geologists is how dense, oceanic upper-mantle and crust are lifted over less-dense continental rocks during subduction, when the same density differences are driving contrary processes at the same time. The process of emplacing ophiolite sequences is called "obduction," and it is thought to be able to move ophiolite suites laterally hundreds of km. It is a major mystery of uniformitarian geology (Oard, 2008). Like many such mysteries, geologists think that more time will solve fundamental problems of physics, and they cite slow tectonic forces as their solution. Agard et al. (2014, p. 132, emphasis added) recently stated:

> Within the frame of plate convergence, obduction (Coleman, 1971) is an apparent geodynamic *anomaly*, whereby fragments of dense oceanic lithosphere—"ophiolites," are emplaced onto light, deeply buried continental margins over distances of several hundred kilometers.

A related problem is the absence of modern analogues (Dilek, 2003). This proposed mechanism thus violates the principle of actualism, the methodological facet of uniformitarianism (Reed, 2010; 2011). Since Miall (2015) claims that uniformitarianism is still geology's fundamental principle, the lack of any modern analogue is troubling. Geologists may argue that it is an extension of the present-day process of subduction, and that it is a natural process, but neither subduction nor obduction is observed. To make interpretation even more difficult, ultra-high-pressure minerals and microdiamonds have been found in an ophiolite in Tibet, implying exhumation from depths up to 250 km (Yang et al., 2007)!

Ophiolites Relatively Common

These problems might be less daunting if ophiolites were rare, but they are

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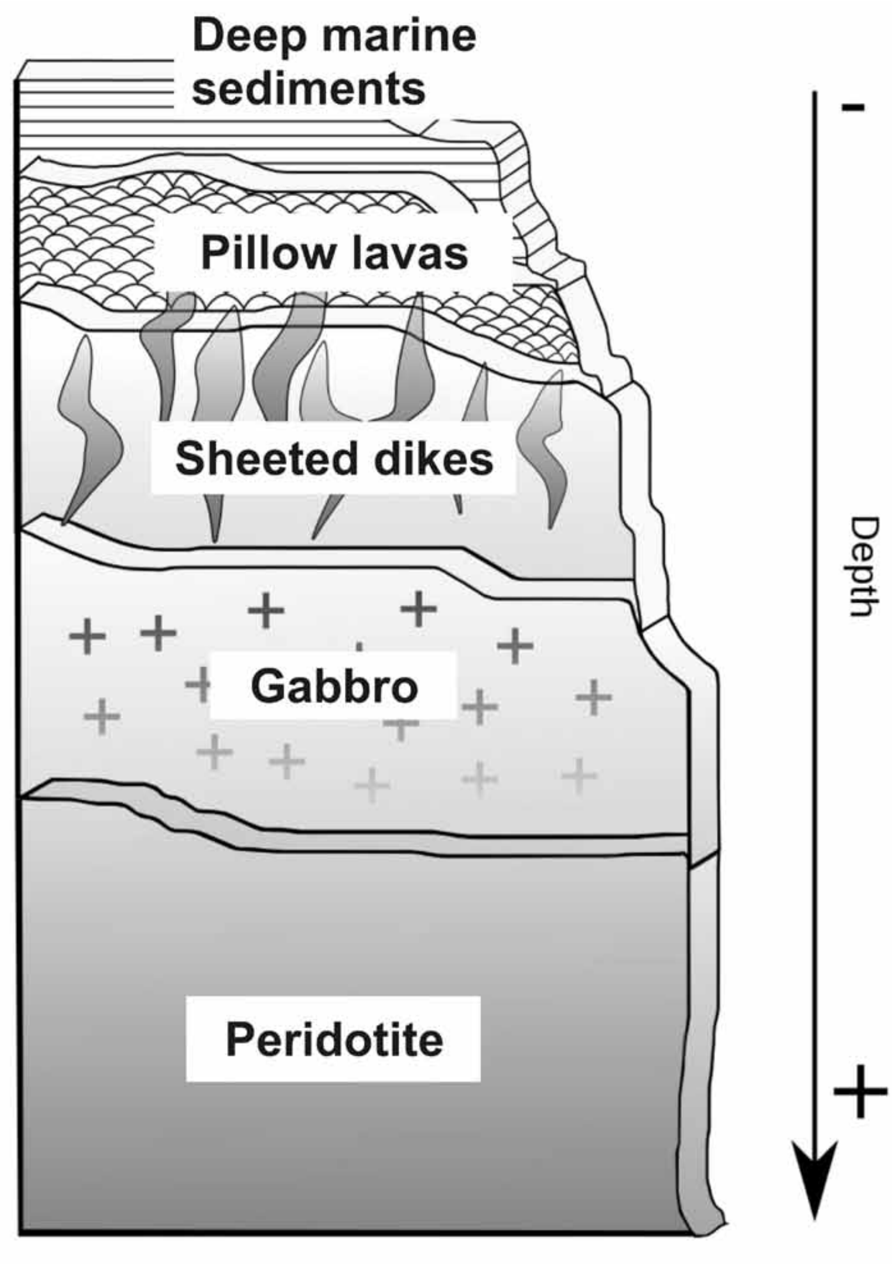

Figure 1. Idealized stratigraphic sequence of an ophiolite (Ofiolita.svg, Wikipedia Commons CC-BY-SA-3.0).

found in most major mountain belts, especially near coastlines (Wikipedia, 2015), such as coastal California and southwest Oregon. They are also found in interior mountains, such as the Alps and Himalayas. Ophiolites also occur in different "subduction settings," such as back-arc basins, island arcs, and forearcs. Back-arc basins are associated with subduction zones, forming opposite trenches across the magmatic zone, supposedly caused by partial melting of the subducting plate. Island arcs are volcanic zones thought to be caused by magma migrating up from the 100–150 km depth of the subducting plate. Forearcs are thick sediment accumulations, supposedly formed as they are "scraped" off of subducting plates. Forearc basins are troughs located between the trench and the magmatic arc.

Geologists have been trying to unravel the mysteries of ophiolites for 50 years (Dilek, 2003). Among the best studied are the Semail ophiolite in Oman and the UAE, the Troodos ophiolite on Cypress, and the Bay of Islands ophiolite on Newfoundland. Others are known in North America—from Vancouver Island, Washington, Oregon, and California to Arizona and even as far as New York (Wikipedia, 2015). Ophiolites have been discovered in the Balkans, Corsica, Iran, Pakistan, Turkey, Morocco, across the Himalayas, Tibet, India, the Philippines, Macquarie Island southeast of Tasmania, Papua New Guinea, New Caledonia, Japan, South Island New Zealand, the Andes, Brazil, Mexico, Baja California, Cuba, Mexico, and Puerto Rico.

Despite the problems, geologists commonly use ophiolites as a surrogate for deep ocean crust and upper mantle not yet reached by drilling and coring. The deepest borehole in oceanic crust is about 1.5 km; oceanic crust averages 6–7 km thick. This correlation necessarily maintains a level of uncertainty; it is based on the theoretical conclusion that ophiolites represent lower crust and upper mantle not directly sampled. However, that conclusion rests on the assumption that ophiolites represent present-day ocean crust. Some geoscientists question this use of ophiolites as surrogates for lower crust and upper mantle (Kearey et al., 2009).

Convoluted Models

Uncertainty is illustrated by the changing models of geologists. They once thought ophiolites formed at mid-ocean ridges but now think they form at subduction zones, based on their geochemistry (Shervais, 2001). For example, the largest ophiolite suite found, the Semail ophiolite, was originally thought to have formed at a mid-ocean ridge (MacLeod et al., 2013). Even if they do form at subduction zones, specific mechanics of ophiolite formation are poorly understood; many models have been proposed to account for their anomalous presence atop continental crust. Some think the horizontal force required to move them is supplied by a mantle superplume, others by an abrupt change in plate velocity, and some by a vertical reversal when continental crust thrusts under ocean lithosphere. The most popular current theory is that ophiolites form as a new mid-ocean ridge forms *above* a subduction zone! Here is part of the complex mechanism proposed by Dewey and Casey (2013, p. 715):

> In this way, an ophiolite complex is developed at a spreading centre within the fore-arc immediately above a subduction zone that allows the [island] arc to fore-arc lithosphere and trench to extend in a trench-parallel direction during spreading. As the arc and fore-arc grow in length, the dehydrating subducting plate hydrates the hot, low-pressure sub-ridge adiabatic, upwelling, mantle melting zone at or near the spreading centre in the shallow wedge to enhance melting and generate boninites. Mantle is supplied to the ridge melting zone via corner flow from the rear of the arc.

The strongest evidence for their theory is a "sandbox experiment" in which materials of various densities were shortened by horizontal forces (Dewey and Casey, 2013). After 35 attempts, the researchers managed to obtain a result that showed continental subduction underneath ocean "lithosphere." However, caution is required due to the gross simplification and problems of scale—from a small box of material to actual crust covering hundreds of km. One of the main scale problems is that horizontal forces are dissipated rapidly, due to the low lateral strength of rocks, and the subsequent difficulty in transmitting forces through hundreds of km of rock.

Creationist Implications

Ophiolites are as much a mystery for Flood models. There are two main problems: the origin of the ophiolite bodies and the origin of the powerful lateral and vertical forces needed to move them. I have previously suggested a possible Flood mechanism, mainly meteorite impacts (Oard, 2008). A popular Flood model is catastrophic plate tectonics. How would this model account for ophiolite emplacement? Hunter (2009) suggested that ophiolites are mixtures of oceanic and continental lithosphere. In his model, hot mantle was brought to its melting point during the Flood, causing the Earth to expand between 95 and 100 km in diameter due to decompression. During this process, there was rapid differentiation and uplift of new ocean and continental crust. As with many other Flood models, this created a significant heat problem (Editor's Forum, 2009).

Ophiolites are found from the Archean to the late Cenozoic; a problem for Flood models assuming the validity of the geological column. Are Precambrian examples pre-Flood oceanic crust and upper mantle? Were Archean ophiolites formed during Creation Week (Snelling, 2009), and if so, why are they similar to Flood-emplaced examples? Or do they imply that Archean and Proterozoic rocks are from the Flood? Other unique Precambrian phenomena, including raindrop imprints, black shale, quartz arenite, and Precambrian impacts, reinforce that these Precambrian ophiolites are from the Flood (Oard, 1992, 2013, 2014).

If Precambrian ophiolites formed in a manner similar to Phanerozoic ophiolites, then the formation of new oceanic crust in the Mesozoic and Cenozoic by catastrophic plate tectonics is called into question. The existence of ophiolites suggests that there was no such replacement of oceanic lithosphere. It is even possible that ophiolites do not represent pre-Flood crust or even oceanic crust at all, since field examples are often missing members relative to the ideal sequence. Is it possible that ophiolites are simply uplifted or obducted mantle? Since scientists have not yet drilled sufficiently deep into oceanic crust, perhaps the compositional models of deep oceanic crust and the underlying mantle are skewed by the assumption that ophiolites represent that sequence.

The presence of ultra-high-pressure minerals (UHPm) in ophiolites, and the inferred vertical uplift of crust and mantle by up to 100 km, must also be explained (Oard, 2015). Meteorite impacts can also account for UHPm, but there have been few attempts to relate the two. Like many other aspects of Flood models, there is much research to be done.

Creationists need to think "outside the box" rather than accept interpretations of geologists and geophysicists, which rely heavily on uniformitarian paleoenvironmental interpretations that generate uncertainty in the current models. For example, the relatively recent idea that most ophiolites originate near subduction zones rather than the mid-ocean rifts suggests geologists do not know. Flood geologists face different uncertainties, especially extremely limited knowledge of the pre-Flood world and the exact processes occurring during the Flood. Some can be approximated by scaling up known processes, but some probably cannot. We must beware of these paleoenvironmental interpretations because the Flood environment was vastly different from those assumed by uniformitarianism (Oard, 1999).

Conclusions

Ophiolites are a mystery to both uniformitarian and Flood geologists. Continued research has not resolved the big questions, particularly in relation to their origin and emplacement. However, they are common, both geographically and stratigraphically. For that reason, more investigation is needed to unlock the mystery behind the patterns and processes involved in ophiolite origins and emplacement.

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