

Manuscript prepared for
Journal of Hobbitlore
2016

A New Synthesis on the Geology of Middle-earth: Genesis, Orogeny and Tectonics

Chris Ingles and Lindy A. Orthia

Australian National Centre for the Public Awareness of Science, The Australian National University.

Correspondence to: u5389628@anu.edu.au

Abstract. In this paper, we discuss and critique existing hypotheses about the geology of Middle-earth in light of current geological theories of planetary formation, mountain building (orogeny) and plate tectonics. We dispute the prevailing tectonic explanation for the major geological features of Middle-earth and Arda on the basis of evidence as yet not fully considered about the formation of the planet Ambar. We propose novel hypotheses to explain many of the features, including by drawing on recent discoveries of lunar geological formations, and identify questions that remain unanswered.

1 Introduction

For nearly 50 years geologists have attempted to decipher the riddle that is Middle-earth. The first paper to be published on the topic was released in 1967 (Howes, 1967), and was followed by a small boom in studies in the early 1970s (Mason, 1975; Reynolds, 1974; McIntosh, 1973). The topic was then largely ignored until the 1990s (Fonstad, 1991; Sarjeant, 1995), with interest reviving in recent years (Kuhn, 2012; Hynes 2012). This

body of work sits within a wider context of scientific engagement with Tolkien's work, with physicists, biologists and climatologists also academically exploring it (for example, Coombs and Read, 1995; Larsen, 2007; Radagast the Brown, 2013). Larsen notes that a relationship has developed between the Tolkien-faithful and scientists, with scientific researchers promoting their disciplines by encouraging readers to think scientifically about a topic they otherwise know well, and Tolkien appreciators generously encouraging the research and engaging with the scientific debates about the works they love. In some quarters this has gone further, with Kuhn, for example, providing examples of how the geosciences in particular should utilise Tolkien's work.

Yet in all that time, most geological studies of Middle-earth have been based on only a subset of Tolkien's work. Specifically, scientists have ignored potentially critical geological information from *The Silmarillion* and the *Ambarkanta (Shaping)*. Of course, these works were not made available to geologists until after the 1970s boom, but those scholars publishing since the 1990s have still tended to dismiss the works as mere "geomythology," thus designating them

unworthy of serious scientific consideration (see Hynes, 2012 for a discussion of this). This seems something of a betrayal of the compact between Tolkien appreciators and scientists.

In this paper, we take the approach that we can only reach a comprehensive geological understanding of Middle-earth if all Tolkien's works and notes are considered. We contend that the act of marginalising *Silmarillion* and *Ambarkanta* information as merely "intended to be mythical" is a lazy approach to the challenge of explaining Middle-earth geology. Outside of geology, there were wizards, talking trees and trolls in Middle-earth, all of which could equally be dismissed by Earth scientists as "too hard to explain." But to eliminate the implausible - *Ambarkanta*, wizards and all - leaves bleak literature and little to discuss. On the other hand, bringing scientific approaches to bear upon the challenge of explaining Middle-earth geology in a way that is consistent with all of Tolkien's work can help us narrow down exactly what elements seem to conflict with current scientific knowledge, and what we can plausibly hypothesise. Science at its best is hailed for its ability to disregard anything previously thought if new, certain information is discovered. We have considered the posthumous releases of Tolkien's work in that light.

As we will show, taking the *Silmarillion* and *Ambarkanta* data seriously results in some profound challenges to received wisdom on Middle-earth geology. Most significantly, it challenges previous authors' detailed theories on how plate tectonics shaped Arda and its lands. A known geology-enthusiast, Tolkien is believed to have followed the progression of continental drift from an untrustworthy hypothesis to an accepted truth (Hynes, 2012). Consequently many scholars have assumed that all of Middle-earth's geological processes were the result of plate tectonics. But continental drift is not just

Ingles and Orthia: Geology of Middle-earth

something that happens, it is a symptom of something larger - it has underlying processes, structures and causes that result in it happening. To determine if or when continental drift did begin, the complete geological sequence of Middle-earth and Arda from beginning to end needs to be established. This means we cannot rely solely on the Third Age map of Middle-earth for our geological studies. We must reconstruct the lands and the planet in earlier times to understand how the Third Age geological and geographical configuration came to be.

This paper therefore, offers a new geological synthesis, by incorporating old theories about Middle-earth geology with recent Earth-based geological research, and all the available works of Tolkien. While some elements remain difficult to explain using current Earth science, we clearly identify what those elements are, and rely on Earth science to interpret the rest. We first discuss the genesis and macro structure of the planet Ambar/Arda. We then devote considerable space to discussing the processes that contributed to mountain building on the planet, in particular in the Middle-earth region, since these processes have been closely associated with plate tectonics by previous scholars. Finally we return to the question of what, if any, impact plate tectonics has had on other aspects of Middle-earth geology and geography.

2 Middle-earth's genesis

To construct Tolkien's world geologically it is first necessary to deconstruct it. The geology of Middle-earth is best studied by examining the initial state of the planet and the realm in which it resides. The planet Ambar is alleged to have been created by the music of angels. Typically, geologists attribute the formation of planets to the accretion of space dust, however the music of

angels, like many theological suggestions, does not alter any geological processes that have begun since the planet's formation. What is of greater concern for a geologist is that upon formation, the planet was relatively flat. Tolkien's *Ambarkanta* Diagrams I and II (*Shaping* 244, 246) show early Ambar was a hemisphere shape, with life residing on the flat top. A thin layer suggesting a crust aligned the flat top, with what must be solid mantle comprising the remainder of the hemisphere.

A hemisphere-like shape alone debunks a space-dust accretion model for Ambar's formation. In addition, the fact that early Ambar was not spherical means it breaks one of the universal conventions for what constitutes a planet (International Astronomical Union). However, it can be classified as a celestial body, like an asteroid. Since there are no further details to suggest how it formed this way, unexplainable processes initiated by the music of angels will suffice.

Ambarkanta Maps IV and V (*Shaping*, 250, 252) show aerial views of a relatively level world, both drawn from a perspective above the supercontinent that became Middle-earth and surrounds. Map IV is a closer view and set prior to the appearance of the sun and moon, shortly after the fall of the Lamps. Without a sun to orbit, Ambar again breaches a planetary convention and raises questions about heat sources to support life. Regardless, Map IV depicts a Northland and Southland of Middle-earth, while Map V displays the entire flat planet, labelling the Middle-earth supercontinent as Hitherlands.

As Maps IV and V represent a very early Middle-earth they can assist in establishing how the world evolved geologically. Tolkien identified the early Ambar mountain ranges, so these provide reference points that can be tracked through time. The mountains of interest are the Blue, Grey, Iron, Yellow and Red Mountains. Although Tolkien drew many

regional maps, he drew few maps of the Hitherland supercontinent that became Middle-earth, but Fonstad's *Atlas of Middle-earth* consolidated Tolkien's maps and geographical descriptions and provided representations of Ambar through the ages. However, she inaccurately described the formation of the mountains, claiming that "The Grey Mountains may originally have been part of the extensive Iron Mountains" (Fonstad, 1991: 78). While this would appear to be the case geographically, Tolkien's *Ambarkanta* Map IV, which is also reproduced in Fonstad's *Atlas*, has the Iron Mountains in the Northland and the Grey Mountains in the Southland. In the *Ambarkanta*, Tolkien also detailed the formation of most of the earliest mountains:

For their further protection the Valar thrust away Middle-earth at the centre and crowded it eastward, so that it was bended ... And the thrusting aside of the land caused also mountains to appear in four ranges, two in the Northland, and two in the Southland; and those in the North were the Blue Mountains in the West side, and the Red Mountains in the East side; and in the South were the Grey Mountains and the Yellow. (*Shaping* 239)

Furthermore, the Grey Mountains cannot have come from the Iron Mountains as the latter were formed at a later date by the evil spirit of the time: "Melko fortified the North and built there the Northern Towers, which are also called the Iron Mountains, and they look southward" (*Shaping* 239).

From their positions in *Ambarkanta* Map IV, the most notable changes were to the Yellow and Grey Mountains. The Yellow either disappeared or joined the Red Mountains to become the Orocarni (Eastern Mountains), best depicted by Fonstad. The Grey Mountains shifted from a North-South trend in the west Southland to an East-West

trend in the Northland, parallel and adjacent to the new Iron Hills. The explanation for this seemingly impossible shuffle is suspected to arise from later land contortions initiated by the inhabitants of Arda:

And the Earth was again broken in the second battle, when Melko was again overthrown ... But the greatest change took place, when the First Design was destroyed, and the Earth was rounded. (*Shaping* 240)

While little was written about it, by the end of the Second Age, Ambar had been altered to become a complete sphere. Assured of a globular shape, geologists can begin to analyse Ambar's structure and composition. Fortunately, Tolkien provided a clue to Ambar's interior in a letter to a fan (*Letters* 183) and later reiterated it in a BBC interview (Gueroult and Tolkien). In both instances Tolkien advised that the planet of Ambar is our planet - in a different time.

Middle-earth is not an imaginary world ... the theatre of my tale is this earth, the one in which we now live, but the historical period is imaginary ... Naturally it feels familiar, even if a little glorified by the enchantment of distance in time. (*Letters* 257)

Worth briefly exploring is the often debated puzzle of the "distance in time". A constant in our universe, time can be plotted as a line for which one end represents the past and the other, the present or future. A distance in time could therefore imply the length between two points, suggesting x amount of time has passed since Middle-earth existed on Earth. This appears to be the consensus among many online Tolkien appreciators and also Howes. However, as discussed by McIntosh, despite similar landmass borders (and similarities in climate as discussed by

Ingles and Orthia: Geology of Middle-earth

Radagast the Brown), it is highly unlikely that Middle-earth became Earth. Instead, another possibility for a "distance in time" is a tangent from the timeline, being the same planet in a different time. Alternatively, and more likely due to the different planetary conventions, Middle-earth could be our Earth in a different universe and therefore different time. Multiverses is a hypothesis that our uni-verse is the mother, daughter or twin of another universe. Endless possibilities exist regarding the physical laws of another universe, which could potentially even result in the formation of hemispherical planetary bodies. Coombs and Read reached a similar conclusion of wormholes and parallel timelines while attempting to determine the physics of Middle-earth. The question arises, however, which universe came first, and without delving into the intricacies of multiverse theory, it seems too time-expensive for a geologist to pursue.

While the "time" riddle remains unsolved, geologists can rejoice that if Ambar was/is our planet, then the geological processes occurring on Middle-earth by the Third Age are the same as those occurring on Earth. This importantly includes weathering, a hydrologic cycle, differentiation, and presumably continental drift.

Summarising the genesis of Tolkien's world, the spherical realm of Arda was first created with a single, terrestrial planetary body, Ambar. Ambar comprised Arda's bottom hemisphere, with life existing on its flat top. Mysterious alterations later resulted in Ambar becoming a spherical planet. This initiated geological processes similar to those on Earth – with exceptions.

3 Middle-earth orogeny

A delightful term used by geologists, orogeny, refers to crustal deformation that results in raised land (mountain building). As

one piece of Earth's crust collides with another, mountains arise. This process was the basis of the work of two geologists, Reynolds and Sarjeant, who both attempted to reconstruct the geology of Middle-earth.

Reynolds, writing in the early 1970s, was the first to use the mountains of Middle-earth as geological clues and proposed tectonic plate margins around them. With the theory of tectonics evolving and continental drift still contested at the time, Reynolds' hypotheses were later updated by Sarjeant in 1992. Both Reynolds (page after 68) and Sarjeant (1995: 337) constructed detailed geological maps of Middle-earth, and both were built on the usually safe assumption that geographical features were clues to geological processes. But neither incorporated information about the genesis and hemispherical shape of Ambar, discussed above, into their hypotheses. While Reynolds can be forgiven as the *Ambarkanta* had not been released, Sarjeant viewed Tolkien's posthumous release as the "equivalent of a geologist's field notes – unrevised and not to be trusted" (Sarjeant, 1995: 334). While discrediting field geologists is debatable, Tolkien also referenced the world becoming round in *The Silmarillion*: "And those that sailed furthest set but a girdle about the Earth and returned weary at last to the place of their beginning; and they said: 'All roads are now bent'" (S 136).

With two Tolkien sources, then, any proposed explanation of Middle-earth geology should take into account the fact that Ambar was partly flat at some time. Sarjeant's interpretation of the geology of Middle-earth in fact contradicts Tolkien. Sarjeant asserted that "collision" between the Forlindon and Eriador Plates "caused the orogeny" that formed the Blue Mountains, despite the *Ambarkanta* advising the Blue, Grey, Iron, Yellow and Red Mountains were formed by the thrusting aside of land on a flat planetary body. Sarjeant (1995: 336) further

elaborated that the Forlindon Plate has been "drawn down into a subduction zone at the continental margin, its materials reincorporated into the earth's mantle." If the world is not round, tectonics cannot be present, or implicated in mountain building. Nor can any comparison be made between Arda's early history and "earth's mantle", when the *Ambarkanta* Diagrams vividly show a significantly different planet. To subduct a piece of crust into the brittle mantle of a flat planet seems equivalent to breaking a shortbread biscuit, taking a bite, then perfectly repairing it. Where does the subducting biscuit go in a brittle, hemisphere planet?

Reynolds' and Sarjeant's proposed presence of at least four individual plates comprising one continent is further puzzling, in that continents on Earth mostly reside on individual plates. Two notable exceptions are California, partly separated from the rest of North America by the San Andreas Fault, and the Indian subcontinent, which collided into the Eurasian plate to form the Himalayas. To contend that several Californias and Indias, all on different tectonic plates, comprise the majority of central-west Middle-earth seems highly unlikely. Australia, for example, is one continent residing on a single tectonic plate, and the mainland of Europe, possibly a base of design for Middle-earth, also resides on a single tectonic plate, which it shares with most of Asia.

Perhaps then, some of Reynolds' divisions may be a case of out-dated language. Sarjeant suggested so, stating that the use of the word "plates" by both was "in modern terminology ... terrans" (Sarjeant, 1995: 336). However, terranes, as they are now known, are the result of subduction, where the falling plate sticks material to the non-subducting plate. Terranes therefore imply subduction, which returns to Sarjeant's impossible, missing biscuit scenario. Furthermore, by the Third Age, most of the mountains of Middle-earth had

already formed, leaving not enough future instances of orogeny to create the many depicted terranes.

If we agree that, at the very least, a theory of Middle-earth geology requires a map with updated terminology, the next question is where all the geological boundaries lie. Reynolds (1974) and Sarjeant (1995) both constructed impressive geological maps of Middle-earth, however both were constructed on an assumption involving tectonic plates and orogeny. By assuming all the mountains in Ambar were built by crustal collisions, the terrane/plate boundaries Reynolds and Sarjeant propose are consequently inaccurate. Whether suggesting four or six plates or terranes in Middle-earth, if the mountains of the First Age were raised in the middle of flat land, they cannot represent the boundaries of either terranes or plates. Consequently, they must be similar to fold-mountains, where the crust has buckled upwards from perpendicular force. The previously flat land - later to become Middle-earth and its surrounds - was much more likely all within one single plate than cut through by plate borders.

To establish if any collisions did occur between different terranes and plates in Middle-earth, we must definitively explain the formation of all Middle-earth's mountain ranges. As discussed above, the Blue, Grey, Iron, Yellow and Red Mountains were all formed before plate tectonics, not from orogeny, and therefore cannot represent plate or terrane boundaries, even taking into consideration later alterations such as the movement of the Grey Mountains across the supercontinent when the world was made spherical. But there were other mountains not in existence on the flat surface of Ambar: the Mountains of Mordor, the Misty Mountains, and the White Mountains. These invite further investigation.

3.1 Mountains of Mordor

A significant orogenous anomaly in Middle-earth is the suspiciously square-like shape of the mountains around Mordor that appeared after Ambar became round, and therefore possibly formed as the result of plate collisions. Comprised of the Mountains of Shadow, Ash Mountains and Mount Doom, they continue to baffle geologists due to their near perfect shape not seen on Earth. Collectively known as the Mordor Volcanics, Reynolds (1974) proposed that the square-like formation was the result of "another small continent or oceanic fragment caught between the two orogenic phases represented by the mountains ringing it to the north and south." Reynolds then expanded that, "continued pressure from the south caused a re-orientation of the direction of plate movements" (Reynolds, 1974: 68). This implies one tectonic plate was squashed between two others, forming two parallel mountain ranges, before changing direction to form a near perpendicular, connecting, third mountain range. This is certainly not seen on Earth, as plates drift away from seafloor spreading, becoming older and colder and eventually subducting below a collision zone. Three orogenous events and a change of plate direction, all credited to continental drift within a short time, is therefore implausible.

McIntosh took a more convincing approach to the shape of the Mordor Volcanics, claiming "the mountains around Mordor were deliberately built as a fence" (McIntosh, 1973: 6-7). This is consistent with Tolkien's work in that, during the Second and Third Ages, Sauron did claim Mordor as home for his protection. Potentially then, the Mordor Volcanics could have been established before the Second Age, and thus before tectonic plates. With only one prior tenant to Sauron, under this hypothesis Mordor's shape would likely be the result of land-contortionist, Melkor/Morgoth, who is

known to have raised other mountains for protection during the First Age: “I am the Elder King: Melkor, first and mightiest of all the Valar, who was before the world, and made it” (*CH* 29). Prior to his capture, freedom and subsequent renaming, it is known Melkor/Morgoth (hereafter, for simplicity’s sake, Morgoth) “reared the threefold peaks of Thangorodrim, and a great reek of dark smoke was ever wreathed about them” (*S* 36). These volcanos were raised to become Morgoth’s first home in the Iron Mountains. It therefore seems highly probable that Mordor was also created by Morgoth to provide protection for his new home, as alluded to by McIntosh prior to the release of *The Silmarillion* and *Ambarkanta*. Without natural occurrences of rectangle mountain ranges on Earth, however, obtaining a geological explanation for the formation of the Mordor Volcanics seems bleak. Unless, that is, we draw comparisons from out of this world, for example comparing Mordor with basins, fissures and craters on Earth’s Moon.

Oceanus Procellarum is a basaltic plain on the Moon (one of the Moon’s mares, or ‘seas’), and, while not an elevated structure, it does display rectangular features visible from Earth (see for example Andrews-Hanna et al., 2014: Fig. 3). While it is unlikely that the Moon provided inspiration for Tolkien’s design, some images of the Procellarum region do show geological similarities in shape between it and Mordor. In this instance, basalt, being former lava, has cooled into a near square shape. As the Moon has never experienced plate tectonics, it may be the relevant comparative to the Mordor contour.

Also of interest are a number of rimas (fissures) that exist on the moon, some of which incorporate 90° shapes similar to the Mordor Volcanics, and were also formed without plate tectonics. Rima Krieger is a striking rima found amid Oceanus Procellarum, with near 90° angles (see for example images in Meyer, 2014,

<http://lroc.sese.asu.edu/posts/776>). While one explanation for rimas is that they are former, collapsed lava tubes, geologists are not sure how they formed into these striking angles and shapes (Meyer, 2014). In the case of Mordor, it seems plausible that Morgoth could have directed a stream of lava into a square shape himself, with assistance from whatever natural processes helped form the Moon’s rimas.

Alternatively, adjacent to Rima Krieger is the Krieger crater, which appears to be a polygonal caldera, or large volcanic crater (see images in Meyer, 2014, <http://lroc.sese.asu.edu/posts/776>). Drawing a parallel with this, Mordor could conceivably have been a supervolcano, similar to Olympus Mons of Mars, that collapsed in on itself after erupting. Sarjeant came to a similar conclusion, labelling it a caldera “like that of Krakatoa” (Sarjeant, 1995: 336), however then decided that it also resides on its own tectonic plate, seemingly entirely surrounded as an unlikely intra-plate plate. Whatever the case, a strictly magmatic beginning provides a far more plausible explanation for Mordor’s origins than does continental drift and subsequent orogeny.

3.2 Misty Mountains

The remaining mountain ranges of Middle-earth to be discussed are the White and Misty Mountains. While nothing was written by Tolkien specifically regarding the formation of the White Mountains, McIntosh was the first to suggest that they “may be a continuation south and east of the structure of the Misty Mountains” (McIntosh, 1973: 6). Fonstad was certain that the White Mountains were present since at least the First Age and agreed that they were “quite likely raised at the same time as the Towers of Mist [Misty Mountains]” (Fonstad, 1991: 179). The hypothesis that the White and Misty Mountains were simultaneously raised

appears hard to disprove due to their almost seamless connection, broken only by the Gap of Rohan, of which they comprise southern and northern walls respectively. The formation of the White Mountains therefore does appear to have coincided with the formation of the Misty Mountains.

By the Third Age, the Misty Mountains were the longest mountain chain in Middle-earth, perilous to the hobbits and other creatures that traversed them. Possibly the most crucial to understanding the continent geologically, each prior geologist has cited different origins for the Misty Mountains, despite clear evidence from Tolkien as to their formation. Howes was the first to identify a Misty Mountain mystery. She argued that Middle-earth was geographically ancestral to Europe, and indeed drew a map in which Middle-earth's boundaries were superimposed over a map of Europe (Howes, 1967: 14). With respect to the Misty Mountains, Howes was not entirely clear but claimed that glaciers had extended from the north twice to influence them. In a potentially historic analysis, she also claimed to have fossilised tree samples from a nearby site in Middle-earth that were isotopically dated to between 100,000 and 200,000 years old.

Challenging Howes' findings, McIntosh (1973) effectively disproved the hypothesis that Middle-earth evolved into Europe, and argued, rather, that continental drift was responsible for the Misty Mountains. McIntosh elaborated that the unhurried collision of tectonic plates squeezed rocks together, and with "nowhere else to go the rocks went upwards" (McIntosh, 1973: 4). Reynolds in contrast did not discuss the formation of the Misty Mountains, however he believed a failed arm of a plate triple-junction, an aulacogen, continued to alter the range. Aulacogens are areas of crustal spreading also known as rifts; a prominent Earth example is the massive East African Rift, which forms a triple junction with the

Ingles and Orthia: Geology of Middle-earth

Red Sea and the Gulf of Aden. Crust grows outwards from the centre of a rift, and as this happens, the older crust is pushed back, heaping rock onto both sides of the rift. The question is whether this mechanism would have been sufficient to form the Misty Mountains.

Sarjeant (1995) supported the spreading hypothesis along the Anduin river and indeed labelled it the Anduin Rift. However, Sarjeant believed the Anduin Rift was created as a result of the collision of two central tectonic plates (which Reynolds, 1974 had named the Eriador and Rhovanion Plates) with two plates on either side of them (the northern Forodwaith Plate and southern Harad Plate). This would effectively be a convergent turned divergent fault, with two colliding plates forming the Misty Mountains, then the subducting plate ceasing movement and a lava spreading ridge appearing adjacently. Sarjeant further suggested that the Anduin Rift then formed a second triple-junction with the rift joining the aulacogens. Orogeny aside, the primary argument against the existence of an Anduin Rift is the location of the Misty Mountains, which reside partially along one side of the Anduin River valley, then curve away in a southwest direction, while the Anduin River curves to the southeast. Rifts are divergent plate boundaries that lead to continual crustal extension perpendicular to the rift. Generally, continental rifts form horst-graben-horst sequences (highland-lowland-highland), with the rift spreading from the graben. If the Anduin area was a rift valley, the great flat forest of Mirkwood, east of the Anduin River, would display land build-up. Sarjeant rightly provides evidence of a horst-graben-horst sequence along the Anduin River, in the form of Eryn Muil, however this is a very small, localised instance in comparison to the large proposed rift and is located to the southeast of the Misty Mountains.

A half-graben could account for mountains being found only on one side of a river. However, this is also debunked by Tolkien's maps, which show that the highland and lowland follow different paths. Furthermore, as the White Mountains were likely formed from the same processes as the Misty Mountains, it is also unlikely that the Anduin River represents a convergent or divergent boundary, for neither could have contributed to the coinciding formation of both the White and Misty Mountain ranges. In any case, the Anduin Rift theory is based on the assumption that the Rift formed at least one triple-junction, which necessitates the existence of tectonic plate boundaries within the continent - and these intracontinental tectonic plates are highly disputable, as discussed above.

An alternative explanation was proposed by Mason (1975), who went against popular belief and proposed that the Misty Mountains were a "fold-mountain chain" composed mostly of volcanic bedrock buckling upwards with regional sediment accumulation. Prior to continental drift becoming accepted among geologists, many of the largest mountains on Earth were believed to be fold-mountains. It is now known that folds may be responsible for many hills, but cannot account for mountain building in high ranges like the Andes or Himalayas. But despite being based on outdated knowledge, Mason's hypothesis of how the Misty Mountains formed aligns most closely with Tolkien's words:

But the mountains were the Hithaegllir, the Towers of Mist upon the borders of Eriador; yet they were taller and more terrible in those days, and were reared by Melkor to hinder the riding of Oromë. (*S* 23)

In other words, as well as being the antagonist of the battles that resulted in the land contortion that moved the Grey Mountains, Morgoth also raised several

volcanos and the Misty Mountains. If we accept the simultaneous formation of the White and Misty Mountains, it seems likely that Morgoth also strategically raised the White Mountains. Doing so would have resulted in only one slim passage through the centre of Middle-earth, Rohan Gap, which tactically would provide a defensive upper-hand in battles taking place between the White and Misty Mountains, for example, that against the Oromë.

Clearly a powerful being, how Morgoth was able to raise land or bend crust remains unknown. However, his mountain-building efforts did involve moving crust upwards, which does occur on Earth. The difference here is only in the type of force being applied and probably the direction. Perhaps, as with Mordor, Morgoth simply enhanced or accelerated natural physical processes to build the Misty Mountains. Since subduction was impossible at the time because land cannot go downwards, any thrusting aside of crust would cause intraplate folding or collisional boundaries where crust can only go up. With the densest material holding its position, any horizontal force would then result in a collision with the lighter crust being *supra*-ducted or *hypo*-ducted above.

Without any further details from Tolkien, it can only be established that mountains were formed similarly to some of those on Earth, either through folding or other non-subduction related orogeny. And, rather than plate tectonics, all of the mountains of Middle-earth were acted upon by an as yet unexplained force that at present we can only label "magic."

4 Middle-earth plate tectonics

If tectonic movement was not responsible for the origin of Middle-earth mountains, can it provide an explanation for any aspect of Middle-earth geology? Another geological

phenomenon often associated with plate tectonics on Earth is volcanic hotspots, and Sarjeant noted that Morgoth's creation of mid-continent volcanos indicates the presence of hotspots in Middle-earth. Hotspots are plume outlets of magma from deep within a planetary body that burst up through the outer crust, resulting in mid-plate volcanos. Over time, a hotspot will produce multiple volcanos in a linear chain, because the magma that forms them is derived from the mantle underneath the drifting crust. While tectonic plates are moving, the plume through the mantle is not, and the direction of the plate movement is indicated by a line of remnant volcanos on the continental or oceanic crust. The islands of Hawaii are great examples of trackable hotspots, with the same plume having built many islands over time, that increase in age with distance from the outlet. On a map of Middle-earth, however, there appears to be no evidence that tectonic plates have shifted, as there are no linear hotspot volcanos. Instead, a simple comparison could again be made to the Moon, Mercury, Venus or Mars, all of which have intraplate hotspots without tectonic plates.

While a lack of hotspot trails may appear to defeat the theory of continental drift, the geological timescale proves it does not. Should tectonics exist, these processes likely began toward the end of the Second Age when the planetary body became round. Therefore by the Third Age, at most several thousands of years before the *Lord of the Rings* map, plate tectonics would only have been present in Middle-earth for a very short geological time period and not long enough to produce linear hotspots. In comparison, each of the individual Hawaiian Islands originated millions of years apart. Of course, Howes did claim to date Middle-earth material to over 100,000 years old, and Reynolds also bravely applied Earth's geological timescale to Middle-earth rock outcrops. However, over such little time, it is highly likely that if

Ingles and Orthia: Geology of Middle-earth

tectonics did exist, they had very little geological impact. This further implies that the orogenous events that occur on Earth over hundreds of thousands of years were yet to begin on Middle-earth.

The answer to whether or not continental drift did exist may come from Howes, who proposed sea-floor spreading was occurring from a mid-ocean ridge west of the Blue Mountains. Howes advocated the existence of the oceanic ridge as part of her theory that Middle-earth had evolved into Europe, marking Earth's Mid-Atlantic Ridge on her map superimposing the two lands/worlds. Fonstad later agreed that the mid-oceanic ridge did likely exist on Middle-earth and subsequently renamed it the "Great Rift," presumably to remove any link to our Earth. She concluded that like plate tectonics, the Great Rift appearance coincided with the end of the Second Age or the beginning of the Third. With a consensus among Middle-earth scholars that tectonics did exist at this time, the Great Rift is likely similar to the Mid-Atlantic Ridge on our Earth as suggested by Howes. Complications do ensue however, as the location of the seafloor spreading is where the subcontinent of Beleriand had previously been. The hurdle here is that crust is usually created at divergent boundaries, not dissolved at them.

4.1 Beleriand: missing

The western extension of Middle-earth, Beleriand, vanished from Tolkien's maps by the Third Age, having mostly sunk into the sea. A curious phenomenon, Tolkien only provided vague clues to explain this:

In the Great Battle and the tumults of the fall of Thangorodrim there were mighty convulsions in the earth, and Beleriand was broken and laid waste; and northward and westward many lands sank beneath the waters of the Great Sea. (*S* 137)

Despite the mysterious aspects of this event, the disappearance of Beleriand is direct evidence of a geological event occurring during the supposedly geomythological era. This is a further argument in favour of incorporating all of Tolkien's works into geological theories without being maligned as myth or inaccurate field notes. Before mostly disappearing, Beleriand was bordered by mountain ranges in the north and adjoined the entire western edge of Third Age Middle-earth. The Blue Mountains, also referred to as Ered Luin on many of Tolkien's maps, were approximately triple their later length during the First Age, and covered more ground than the Misty Mountains of the Third.

Once we expand the map of Middle-earth to incorporate Beleriand (Figure 1), the continent begins to resemble something closer to what might be seen on Earth. Accordingly, Sarjeant's six tectonic plates in Middle-earth appear further unlikely, for that would suggest perhaps five more plates in Beleriand. To reiterate, the entirety of Europe practically resides on one tectonic plate, which it shares with most of Asia.

Analysis inevitably turns to how "convulsions in the earth" could cause Beleriand to become "broken" and mostly sink into the sea. An impressive feat, the western edge of Middle-earth appears to have been subsumed but not subducted. A simpler geological explanation could be that rather than most of Beleriand sinking, sea levels instead may have risen. Our own Earth is all too familiar with climate change and the subsequent thermal expansion of the oceans - the islands of Oceania can further relate to disappearing land. Howes mentioned that amid suspected ice ages in Middle-earth, great glaciers were formed and melted, constantly changing the sea levels on Arda, however this would not cause the earth to "convulse." It seems there is no straightforward geological answer to the Beleriand conundrum, which while potentially unappealing to study, should

still not be disregarded in any geological construction of Middle-earth. When plotting any faults on the Third Age map, Beleriand must be taken into account for it comprised a large portion of Middle-earth until its downfall at the end of the First Age. The vagueness of Beleriand's demise merely adds to the mystery. From Tolkien's *Annals of Beleriand*, "So ended the First Age of the World and Beleriand was no more" (*Shaping* 311).

Perhaps then a massive normal fault (a fault which results in the landmass on one side sliding downwards relative to the other side) formed during the battles of the Great War and fall of the volcanoes of Thangorodrim. The fault would have to have separated Beleriand from Middle-earth, subsuming rather than subducting, and resulting in a continental horst-graben. The resulting displacement, however, after dropping a subcontinent into the ocean, would have noticeably raised sea levels and resulted in great tsunamis. The proposed fault then was likely west of the Blue Mountains, perhaps along the line of the River Gelion, which is coincidentally the same location of the later Great Rift. This becomes a plausible hypothesis only if we further assume that the sea level rose sufficiently to also cover the land remaining between the east bank of the River Gelion/the normal fault and what was to become the west coast of Middle-earth.

5 Conclusion

Tolkien intended Middle-earth to align with our Earth in many particulars, but his descriptions of early Arda and the extraordinary events that ensued suggest the geology of Middle-earth (if not its underlying laws and processes) was vastly different from our planet. Prior to Ambar becoming spherical, plate tectonics could not have existed, suggesting there may be closer

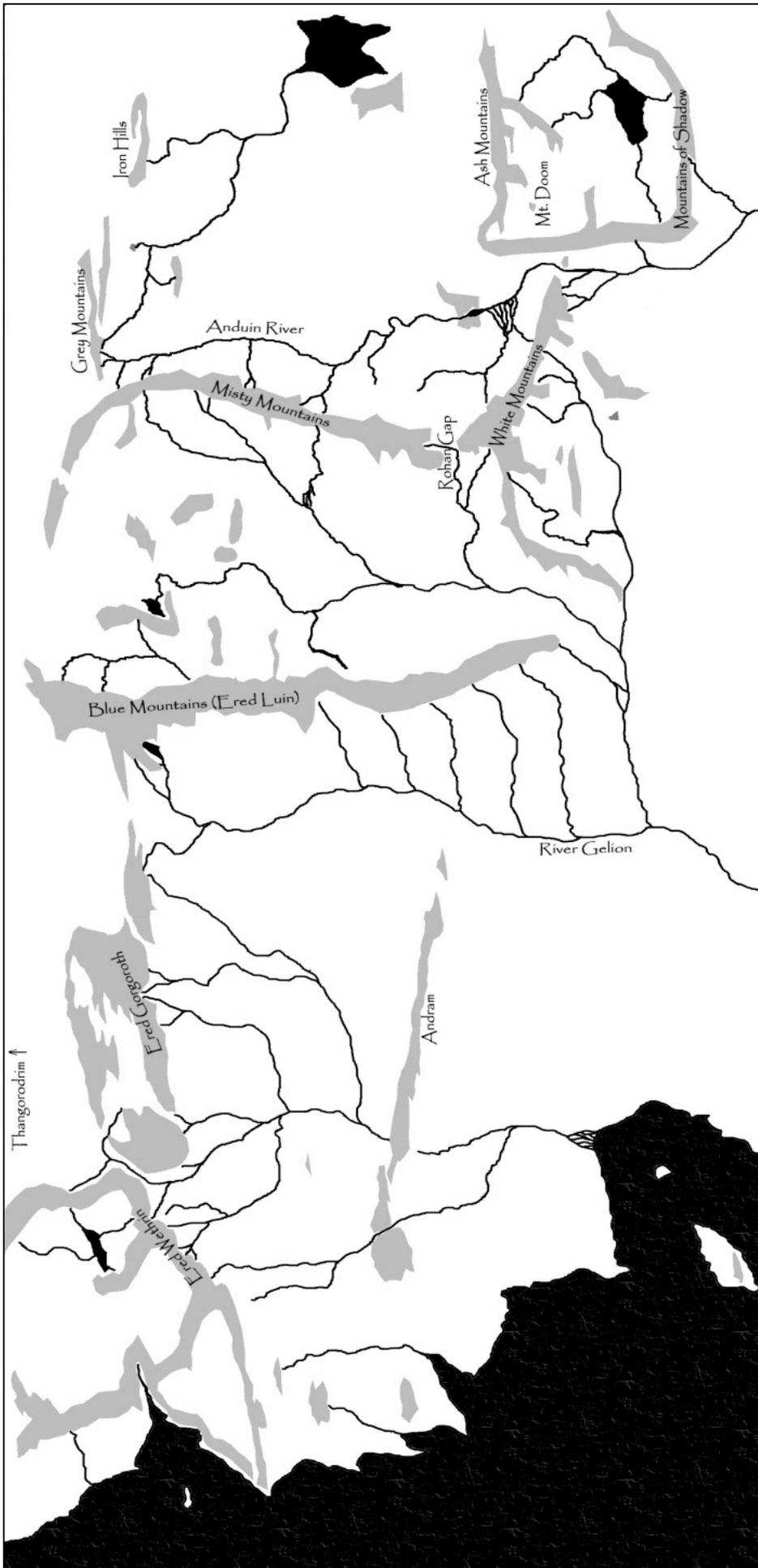


Fig. 1 The *Silmarillion* map aligned with the *Lord of the Rings* map. For continuity the coastline was removed from the *Lord of the Rings* map and the Anduin and Gwathlo rivers extended to the Harnen River and River Gelion respectively.

resemblances between early Ambar and other celestial bodies that similarly lack continental drift. Our new synthesis incorporates this critical information, and in doing so has challenged much of the existing scholarship on this topic. We have attempted to offer a consistent new set of explanations for the geological phenomena observed in Middle-earth that rely very little upon plate tectonics and also incorporate new geological knowledge, for example research into lunar structures. Nonetheless we have still left some elements of the big picture unresolved, and hope that future scholars will be able to further our understanding of these, perhaps with the help of future geological research here on Earth or elsewhere in the solar system.

There are also a number of interesting geological phenomena in Middle-earth that we have not had space to discuss here, such as trolls crafted from and turning into trollstone, and stone-giants, whose constant hostilities with each other must lead to great dispersal of their stone across Middle-earth. These unique types of rock or mineral have not yet been incorporated into geological surveys of Middle-earth. Weathering, differentiation and mithril – many geological anomalies still remain to be explored.

Tolkien was a master at language and his intricate notes suggest much thought went into every aspect of Arda. While the geology of Middle-earth may seem obscure in places and potentially difficult to explain using contemporary Earth science, just because it is not a simple task does not imply it should be avoided. Importantly, these geological riddles should be solved rather than dismissed, perhaps purely for Tolkien's sake, who once remarked when analysing his own work, "Much of my own book puzzles me" (*Letters* 183).

References

- Andrews-Hanna, Jeffrey C, et al. "Structure and evolution of the lunar Procellarum region as revealed by GRAIL gravity data." *Nature* 514.7520 (2014): 68-71. 10.1038/nature13697.
- Coombs, Jenny, and Marc Read. "A Physics of Middle-earth." *Proceedings of the J.R.R. Tolkien Centenary Conference, Keble College, Oxford, England, 17-24 August 1992*. Ed. Reynolds, Patricia and Glen H GoodKnights. Oxford, England: Tolkien Society, 1995.
- Fonstad, Karen Wynn. *The Atlas of Middle-Earth (Revised Edition)*. Boston: Houghton Mifflin, 1991.
- Gueroult, Denys, and J R R Tolkien. "An Interview with J.R.R.T. [Transcript]". 2008. *Tolkien Library*. 16 October 2015. <<http://www.tolkienlibrary.com/press/804-Tolkien-1971-BBC-Interview.php>>.
- Howes, Margaret M. "The Elder Ages and the later glaciations of the Pleistocene Epoch." *Tolkien Journal* 3.2 (1967): 3-15.
- Hynes, Gerard. "'Beneath the Earth's dark keel': Tolkien and Geology." *Tolkien Studies* 9 (2012): 21-36. 10.1353/tks.2012.0005.
- International Astronomical Union. "Resolution B5: Definition of a Planet in the Solar System". 2006. *IAU Resolutions*. 21 October 2015. <https://www.iau.org/static/resolutions/Resolution_GA26-5-6.pdf>.
- Kuhn, N J. "Teaching with Tolkien: environmental degradation of a fantasy world." *European Geosciences Union General Assembly, Vienna, Austria, 22-27 April 2012*. 2012.
- Larsen, Kristine. "SAURON, Mount Doom, and Elvish Moths: The Influence of Tolkien on Modern Science." *Tolkien Studies* 4 (2007): 223-34. 10.1353/tks.2007.0024.

- Mason, R. "The Geology of Middle-earth." *Mallorn* 9 (1975): 12-15.
- McIntosh, P. "The geology of Middle-earth." *Mallorn* 7 (1973): 3-7.
- Meyer, H. "A Kink in Rima Krieger". 2014. *Lunar Reconnaissance Orbiter Camera*. Ed. Arizona State University School of Earth & Space Exploration. 20 October 2015. <<http://lroc.sese.asu.edu/posts/776>>.
- Radagast the Brown. "The Climate of Middle-earth". 2013. <<http://www.bristol.ac.uk/university/media/press/10013-english.pdf>>.
- Reynolds, Robert C. "The geomorphology of Middle-Earth." *The Swansea Geographer* 11 (1974): 67-71.
- Sarjeant, William Antony Swithin. "The Geology of Middle-earth." *Proceedings of the J.R.R. Tolkien Centenary Conference, Keble College, Oxford, England, 17-24 August 1992*. Ed. Reynolds, Patricia and Glen H GoodKnights. Oxford, England: Tolkien Society, 1995.