Three Ways to Make New Hampshire's White Mountains

Preprint · June 2022

1 author:

Woodrow Denham
Unaffiliated

Three Ways to Make New Hampshire's White Mountains

Woodrow W. Denham, PhD
Retired Independent Scholar
wwdenham@gmail.com

Contents.

Abstract.

This article seeks to clarify the roles of *plate tectonics, orogenic mountain building* and *mantle plumes* in creating the White Mountains of New Hampshire. It uses statistical pattern detection procedures with datasets that appear to have been ignored heretofore. Building primarily on Karl Popper's (1963) *Conjectures and Refutations*, I propose hypotheses or conjectures and invite colleagues to refute them. My objective is to frame new questions, not to struggle with old ones that are intractable.

Problems.

This article examines the roles of orogenies, plate tectonics and mantle plumes in building the White Mountains of New Hampshire[1].

I agree with an editorial reviewer who said that *The Geology of New Hampshire's White Mountains* by J.D. Eusden's Team[2] (2013) is "A great new illustrated book examining

[1] In this article, all references to the White Mountains pertain exclusively to the White Mountains of New Hampshire.
[2] The authors include John Dykstra Eusden, Woodrow B. Thompson, Brian K. Fowler, P. Thom Davis, W. A. Bothner, Richard Boisvert and John W. Creasy. Henceforth I refer to them as "Eusden's Team (2013)".

how geologic events and forces created the landscape of New Hampshire's White Mountains". But, as is true of all good books, it is imperfect. For example, on pages 77-80 of the book, the authors indicated their awareness of a major theoretical debate about tectonic plate theory and mantle plume theory that has characterized New England geology for the last half-century (Foulger 2010; McHone 2003; Rollinson 2012). Elsewhere in the book, they present two or more competing hypotheses when similar problematic issues arise, but not in this case. The pages in question acknowledge the problem but treat it as if everyone knows it has been resolved in favor of plate theory.

Further reading of related articles quickly informed me that their decision was consistent with the fact that other relevant and recent papers that are available on the web often do exactly the opposite; i.e., they adopt plume theory and ignore plate theory.[3]

This is the crux of the problem. It has nothing to do with Eusden's Team (2013) *per se.* Rather it is a sign of our times and a major – perhaps a global - cultural problem: in-groups systematically do not talk with out-groups. It is bad enough when that happens among political, religious, ethnic and similar social groups, but it is even worse when it happens among scientists. Here I do not argue for or against plates or plumes. As a broadly focused practitioner of scientific research, I argue against ignoring either side of a debate unless one side has been ruled out unambiguously.

Since I discuss tectonic plates and mantle plumes below, a one-paragraph summary of my understanding of those topics is in order here. The theory of plate tectonics says that the Earth's solid outer crust is separated into plates that *move horizontally* over the molten upper portion of the mantle. Oceanic and continental plates varying in diameter from hundreds to thousands of kilometers come together, spread apart, and generally *interact volcanically at plate margins;* i.e., they slide past, duck under or bump into each other. The theory of mantle plumes acknowledges the importance of plates but also deals with localized columns of hot magma that *rise vertically* by convection in the mantle and generally interact volcanically at "hot spots" such as the Hawaiian Islands and Yellowstone Park, *sometimes but not always remote from plate margins*.

Differences between these theories are not trivial, and they apply directly to research with the White Mountains, the nearby Monteregian Hills in Quebec, the seamounts or submarine mountains off the coast of Massachusetts, and several other points of interest that lie further afield. The mantle plume in question goes by several names, the most common of which may be the New England Mantle Plume (NEMP), and in a slightly different sense is known as the New England Hotspot Track (NEHT). To decode abbreviations and related words throughout this article, please use Appendix A as needed.

---

[3] Since the asteroid impact hypothesis seems to be irrelevant here, I have omitted it.

Roots of this debate appear in a series of publications from a half-century ago. They include McGregor and Krauss (1972:1 magnetics and submarine topography) who argued in favor of plume theory for the Corner Rise seamounts, Duncan (1984 radiometric age dating) who did the same for the New England seamounts, Verhoef (1984:137 depth anomalies) who argued in favor of plate theory regarding the Great Meteor guyot[4], and recently Chamov et al (2019) who studied "sediments dredged from the Atlantis, Plato, and Cruiser seamounts" but remained silent concerning plates and plumes. The argument has expanded exponentially to include the White Mountains and adjacent regions. See the map in Figure 3 for a comprehensive overview of relevant geological features in Quebec, New Hampshire and the Atlantic Ocean.

Koppers et al (2021a:382) present a current review that synthesizes geophysical, geodynamic and geochemical constraints on mantle plumes. It features 57 mantle plumes worldwide (Koppers et al 2021b) and 344 references that deal with them, and opens with a warning:

> "… owing to difficulties in resolving mantle upwellings with geophysical images and discrepancies in interpretations of geochemical and geochronological data, the origin, dynamics and composition of plumes and their links to plate tectonics are still contested."

One of many egregious contemporary examples of the problem as I see it is provided by the influential National Oceanographic and Atmospheric Administration's (NOAA) *Ocean Explorer* website (NOAA/Watling 2003). That site repeatedly emphasizes the role of the NEMP in shaping the geological history of New England and adjacent areas in Canada and on the floor of the Atlantic Ocean. In turn, the assertion by NOAA/Watling (2003) has been cited uncritically by other scholars and government agencies regarding the formation of the New England Seamounts, the Corner Rise Seamounts (Food and Agriculture Organization of the United Nations (FAO) 2021) and the Great Meteor Guyot in the eastern Atlantic. This chain of sources does not cite or allude to the theoretical position adopted by Eusden's Team (2013). In a loose sense, widespread advocacy of the mantle plume's history as described by NOAA/Watling (2003) has become something resembling an unofficial US government endorsement of a questionable hypothesis, potentially a political and cultural problem as well as a technical problem.

[4] A guyot is a late stage in the development of an underwater volcanic mountain or seamount. Think of it as an extinct volcano that is sinking back toward the ocean floor. It must stand at least 900 m (3,000 ft) tall above the seabed and must have a flat, eroded top that is at least 200 m (660 ft) below the surface of the sea (definition synthesized from multiple sources).

Perhaps both Eusden's Team (2013) and the anonymous authors of the NOAA and FAO websites omitted references to their opponents to avoid controversies that could disrupt the flow of their arguments, and I am sympathetic to that reasoning. But the theoretical problems have not been resolved and in my opinion ignoring or suppressing them weakens rather than strengthens publications on both sides of the issue.

My objective here is not to test rigorously the two competing theories and rule out the one that fails, for I suspect that neither is fatally flawed. Rather I propose to conduct an informal series of thought experiments or conjectures in which I consider some of the important differences between the implications of plate theory used alone and plate theory used in conjunction with plume theory. In other words, I frame the issue in terms of sociological complexity, cooperation and multicausality rather than technological simplicity, competition and monocausality.

Focusing exclusively on plate theory enabled Eusden's Team (2013) to limit their field of inquiry to the core of the White Mountains as shown in the red boxes in Figures 3 and 4, pp.16-17. Introducing plume theory necessarily broadens the focus. Here I use both theories, plate and plume, not because I consider the authors' choice to be incorrect, but because I believe that adding plume theory to the narrowly focused plate theory provides a more exciting and productive way to engage issues addressed in their book. At the same time however, incorporating plume theory into the mix introduces numerous and sizeable complexities, both scientific and aesthetic, that plate theory by itself avoids. Everything has up-sides and down-sides.

Findings.

The White Mountains of New Hampshire appear to have been built by three distinctly different geological processes. Evidence has been presented by Eusden's Team (2013) for the role of the Appalachian Orogeny in building Mt. Washington and the Presidential Range, and I accept that argument. A plausible argument has been made by Eusden's Team (2013) for a tectonic process that emplaced the 200-155 Ma[5] White Mountain batholith, a huge globule of molten rock that cooled and solidified beneath the Earth's surface near the base of Mt. Washington, and I accept that argument so long as it is limited to the batholith and to analogous but much smaller plutons of the same age range. However, my conjecture is that the NEMP emplaced the 130-100 Ma plutons separately from – but in locations parallel with – the batholith.

[5] Ka = "thousands of years (ago)", Ma = "millions of years (ago)", Ga = "billions of years (ago)". All dates bearing these abbreviations are approximate, some more than others.

I suggest that the tradition of conflating these two sets of intrusions, then attempting to account for the emplacement of both with the same theory – either plate or plume – is counterproductive. Rather, I treat them as two distinctly different events, the early one understandable in terms of plate theory, the more recent one in terms of plume theory. The result is a fundamental change in important questions about these mountains. Instead of asking whether plate or plume theory accounts for the data, we can acknowledge that plate and plume theory are equally applicable but at different times and places. The fundamental question then becomes: What accounts for the emergence of three distinctly different "kinds" of mountains, built by three different processes, at precisely the same spot, namely Mt. Washington?

The second finding concerns the highly complex hotspot track hypothetically left behind by the proposed plume. This track is unlike the tracks generated by the Hawaiian-Emperor plume and many other plumes in strictly oceanic settings. Also, it is unlike the continental tracks associated with plumes at Yellowstone, the Afar Triangle and Iceland. My cautious conjecture is that this one began by generating an enormous continental flood basalt, called the Mackenzie Large Igneous Province or MLIP, on Victoria Island and adjacent regions in the Canadian Central Arctic in or near 1267 Ma. Next in the line of its development is the Canadian Shield craton, the ancient geologic core of the North American continent, perforated by hundreds of small volcanic pipes hosting a few enormously rich diamond mines; next come the Monteregian Hills of Quebec and the White Mountains of New Hampshire that are set in the St Lawrence Platform and the Appalachian Orogen; then comes the continental shelf and the Atlantic abyssal plain at or near Boston that supports two massive fields of seamounts; then comes the Mid-Atlantic Ridge; and finally it ends at numerous possible destinations on the African tectonic plate or possibly at some unknown terminal point under a North African craton. It is not "just another mantle plume". In terms of both diversity and complexity, the continental and oceanic crusts that have passed over it contrast sharply with those of virtually all other known mantle plumes. Focusing on the plume itself or on individual isolated points in its history misses the big picture framed by the 6,561 km length of the entire track, excluding a possible unknown extension under Africa.

Clarifying relations between plate and plume processes, attempting to understand precisely how three significantly different kinds of mountains emerged at one and the same spot in northern New Hampshire, and rethinking the nature of the entire plume track collectively alters our perception of major events in Earth history.

Methods.

Building primarily on Popper's (1963) *Conjectures and Refutations* in the philosophy of science, I propose several hypotheses or conjectures or suggestions and invite my colleagues to refute them. My objective is to frame new questions, not to struggle with old ones that have proven to be intractable.

Although I am a cultural anthropologist and a specialist in Australian Aboriginal kinship systems, I have a long-standing interest in the philosophy and history of geology. Historical research for this article entailed recapitulating and refining that interest. I began with Albritton (1975) and revisited Occam's razor (Merriam-Webster. n.d.), Ussher's (Britannica 2021) Biblical catastrophism, Hutton's (1785) and Lyell's (1830) uniformitarianism, Winchester (2001) on Smith's (1815) "first true geological map of anywhere in the world", Darwin's (1859) evolutionism, Wegener's (1912/1966) continental drift and plate theory, Lovejoy's (1936) great chain of being, Wilson's (1963) and Morgan's (1971) plume theory, and Eldredge and Gould's (1972) punctuated equilibria, thus closing the historical circle with an updated version of catastrophism.

My being an anthropologist with an interest in the history of geology is analogous to Alfred Wegener's being a meteorologist with an interest in what is known now as plate tectonics. According to Winchester (2003:69-75) and others, Wegener's protracted argument in favor of his hypothesis was seriously problematic, having little to do with data and much to do with cultural issues such as religion, other preconceived notions and turf wars.

> "Wegener was a generalist, interested in everything, content to step outside the perimeters of his own science - meteorology - and to dabble in the wide variety of other unrelated sciences that fascinated him. Scientific specialists, who still today guard jealously their own fields of research, attacked him roundly for daring to invade their territories" (p.69). The rest of the academic community was implacably hostile to his arguments for continental drift and plate theory. [Various rejectors said:] "Utter, damned rot!" "If we are to believe this hypothesis, we must forget everything we have learned in the last seventy years ...". "Anyone who valued his reputation for scientific sanity ... would never dare support such a theory" (p.74). (Winchester 2003:69-75).

The conflict continued for about forty years until Wegener - long since dead - finally won the battle for the acceptance of his hypothesis. It would be good if this fragment of cultural history would not repeat itself.

Current literature searches on the web entailed examining recent geological publications and older technical reports that are accessible to people lacking formal credentials and current affiliations in geology. The exciting proliferation of published and unpublished documents concerning intellectual "hotspots" such as plate tectonics, mantle plumes, large igneous provinces and mass extinctions makes it almost impossible for a novice of whatever degree to come up to speed in a reasonable span of time. Furthermore, despite expansion of open access publishing, many (most?) recent and important geological publications remain locked away behind paywalls, thus violating the long-standing ideal of publishing one's data so that results are reproducible.

Amidst these difficulties, I am grateful to people at Google, Wikipedia, ResearchGate and a wide range of similar services that have enabled my research. I have not knowingly plagiarized anything, but by relying heavily on online services such as these I may have accidentally failed to edit some quotations that I shall correct immediately if readers report them to me. Much to my chagrin, I am certain that my extended literature review missed many relevant and important papers. Specifically, during the last six months I have searched the web diligently for any article that my argument duplicates and have found nothing. Please inform me if you know of uncited publications that duplicate, refute or support my argument.

I derived my results by using supervised pattern detection (SPD) and unsupervised pattern detection (UPD) procedures (Hand 2002) with statistical datasets that appear to have been ignored heretofore. SPD identifies an input pattern such as a novel ring structure as a member of a predefined class; e.g., “that newly discovered ring structure is a caldera”. UPD sorts input patterns into clusters that can be defined in the future as distinctive classes; e.g., “Let's call this new cluster of ring structures ‘impact craters’, then call the next new cluster ‘calderas’, and finally call the last new cluster ‘ring dikes’“. Thus, SPD assigns items to preexisting classes, whereas UPD simultaneously creates or discovers new clusters or classes and assigns items to them. See Appendix E concerning the classification of ring structures.

Mount Washington and the Presidential Range.

In this section of the article, I summarize my understanding of the argument about building up and tearing down the White Mountains that Eusden's Team (2013) made in Chapters 3 through 6. In the brief timeline that appears below, I focus specifically on the sequence of events that occurred during the last billion years concerning Mt. Washington and the Presidential Range as seen from the perspective of plate theory. I remain silent concerning other chapters in their book and say nothing about glaciation.

It may be useful to refresh your memory concerning sizes, shapes and locations of present-day tectonic plates and the continents that occupy them. Please open Appendix A, enlarge it to view the images more easily, and look at the simplified map of Earth's principal tectonic plates. Most action described in this article occurs on the North

American Plate, some occurs on the African Plate, and the rest occurs at interfaces between North American, European and African plates.

The authors begin Chapter 3 with a fitting touch of sardonic humor that makes theirs seem to be an impossible task:

> "To understand this story is like trying to reconstruct a sequence of multiple car crashes that occurred on different days, each time involving multiple cars … when only bits and pieces of the cars are left to [examine] and you cannot go inside the wreck to study the details …" (Eusden's Team 2013:47).

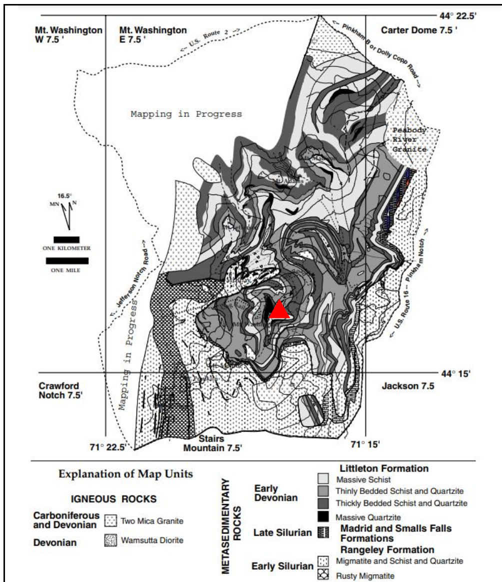
The following timeline works best when analyzed from both directions, counterintuitively beginning at the end of the historical sequence, then re-winding the timeline to a billion years ago and running it in the other direction.

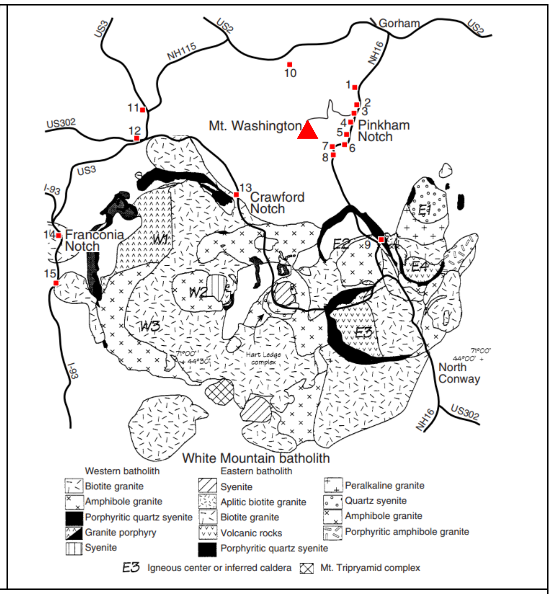
Today. Here I begin at the *end* of the historical sequence, at the present time, in March 2022. The White Mountains cover an area of about 8909 km^2 / 3440 mi^2 and are subdivided into ranges including Presidential, Franconia, Sandwich and many others. In total it includes 48 peaks that reach or exceed an elevation of 1219 m / 4000 ft above sea level. All the peaks look old and somewhat rounded unlike the higher, more rugged mountains of the western United States. But the Presidentials are a bit higher on average than their neighboring ranges and include Mount Washington which, at 1917 m / 6288 ft, is the highest mountain in eastern North America.[6]

These mountains are universally attractive and generally resemble each other in appearance when viewed from the outside, but in my opinion are a lot more interesting when viewed from the inside, even though that is hard to do. Appendix C introduces the bedrock geology of New Hampshire and Appendix D introduces the current landscape featuring Franconia Notch (I-93), Crawford Notch (US-302) and Pinkham Notch (NH-16) as they define implicit White Mountain quadrants: NW (null), NE, SE and SW.

Figure 1 shows the *northeast quadrant* of the White Mountains focusing on the insides of Mount Washington, other mountains in the Presidential Range and some of their near neighbors. They are especially old, gnarled, twisted, fractured and compressed by the ancient processes of orogeny in which a section of the earth's crust was folded and deformed tectonically yielding long term lateral compression that produced a mountain range[7].

[6] Wikipedia 2022a. White Mountains (New Hampshire): confirm area, elevation, number of 4000 footers.
[7] Ultimately geology is all about three types of rocks whose formation and decomposition are cyclical. IGNEOUS rocks are formed from magma, the molten or semi-molten material beneath Earth's surface from which all rocks are formed. Magma that remains beneath Earth's surface may solidify slowly and become





Figures 1 and 2 are drawn to different scales. Use these hints to adjust for differences.
US Route 2 is at the top of each figure
NH Route 16 is at the right side of each figure
A red triangle ▲ indicates the approximate location of Mt. Washington whenever it appears on a Figure.

Figure 1. Generalized bedrock geology of the Presidential Range, New Hampshire (Allen et al. 2001:C-4), **northeast quadrant.**	Figure 2. Geologic map of the White Mountain batholith with locations of field trip stops (numbered squares) and main highways **(**Allen et al. 2001:C-6), **southwest and southeast quadrants.**

Figure 2 shows the s*outhwest and southeast quadrants* that are occupied by the batholith. The process of intrusion forced melted rock between or through existing formations of older rock where it solidified without reaching the surface. It underlies the Franconia and Sandwich Ranges and their neighbors. The intrusions are much younger than the orogenies, they were emplaced by different processes using different materials, and they look strikingly different from each other. Furthermore, older intrusions were emplaced at 200-155 Ma and younger ones at 130-100 Ma (Eby 1995).

granite that intrudes into empty spaces, often as small globular blobs called plutons and large ones called batholiths. Magma that is ejected or extruded onto Earth's surface may solidify more rapidly and become basalt that spreads across the surface as seabeds, lava fields and volcanic cones.
SEDIMENTARY rock is produced by accumulation, compression and cementation of fragmentary materials such as rock debris, mixed minerals, silica/sandstone and calcium/limestone.
METAMORPHIC rock is produced by heating, compressing and twisting other rock types and often is associated with tectonic plate processes. TECTONIC PLATE motions gradually return all three rock types to the subsurface magma state where they began, and the rock cycle repeats continuously.

In Figure 2, the two-part *batholith* was built up from seven *plutons* functioning as *centers of magmatism*.[8] They were intruded near but not directly under the base of Mount Washington. The southwest quadrant has three igneous centers W1-W3, two of them formed at 186-192 Ma, each with distinctive kinds of igneous rocks. The southeast component has four equally distinctive centers E1-E4 (Allen et al. 2001:C-6) that formed about 175 Ma (Eusden's Team 2013:80). Thus, all these intrusions are members of the older 200-155 Ma series, and none belong to the younger 130-100 series. Looked at from inside the mountains, the batholith conveys to me a general impression of a gigantic pair of stuffed pillows while Mount Washington conveys an impression of a huge pile of twisted and shattered rubble. Striking differences between these two present day Figures raise questions about their histories.

Yesterday. In Table 1, I begin at the *beginning* of the historical sequence – or at least at an early point in it – at 1000 Ma, and follow a tightly edited historical timeline, slightly more than two pages long, that highlights events and processes underlying the creation and development of the White Mountains as we see them today. In the table, estimated absolute dates appear in the left-hand column while estimated relative dates appear in the right-hand column. Please use the International Chronostratigraphic Chart (ICS-21) in Appendix B for clarification.

My comments in the table are, to the best of my ability, quotations, summaries or paraphrases of statements by Eusden's Team (2013) or of materials quoted or cited by Eusten's Team. This note serves as a citation for all of them.

Eusden's Team (2013) presents an argument that deals with Wilson Cycles (aggregation/disaggregation of unified ocean basins) and Supercontinent Cycles (aggregation/disaggregation of unified continental landmasses) which may be carefully distinguished from each other or used interchangeably as needed.

In Table 1, Chapters 3 and 4 deal exclusively with Figure 1, Chapter 5 deals exclusively with Figure 2, and Chapter 6 deals with both Figures 1 and 2.

---

[8] The terms used here are difficult and confusing. *Magmatic activity* is the production, intrusion and extrusion of magma, the molten rock material under the earth's crust from which igneous rock is formed by cooling. A pluton or batholith, which may represent the magma chamber (space) of an extinct volcano or a magma body that never produced any eruptions, probably crystallized several km below the Earth's surface. A *pluton* is a relatively small intrusive body (a few to tens of km across) that seems to represent one fossilized magma chamber. A *batholith* is much larger (up to hundreds of km long and 100 km across) and consists of many – sometimes thousands of **-** plutons that are similar in composition and appearance.

Chapter 3A deals very broadly with the disaggregation of the supercontinent Rodinia and the simultaneous aggregation of the supercontinent Pangaea between 1000 ma and 252 Ma. In Plain English, Chapter 3A deals with the orogenies that produced Pangaea.

Ma	***Chapter 3. Disaggregation of Rodinia and aggregation of Pangaea***
Ch. 3A	***1000-252 Ma. Pre-Pangaea Appalachian tectonics***
1000	Rodinia supercontinent aggregation occurred
1000-541 825-550	**Neoproterozoic** – Rodinia supercontinent disaggregation (rifting/deconstruction) occurred Yielded formation of Laurentia Continental plate – passive south margin with sand, clay, limestone; sedimentary, not igneous Yielded formation of Gondwana Continental plate – active north margin with complex, active, destructive plate boundary – much volcanism and rifting of Ganderian, Avalon, Meguma ribbon plates; earthquakes; igneous, not sedimentary; some metamorphosis?
541-485 500 485-443 455 450	**Cambrian** **Taconic Orogeny** **Ordovician** Laurentia accreted in bits and pieces Major messy accretions – "a fantastic series of collisions" – much volcanic activity, faulting, deformation, metamorphosis ensued
444 – 419 420	**Silurian** **Salinic Orogeny** – Laurentia accreted Ganderian, Avalon, Meguma ribbon plates
419-358 400 380 360	**Devonian** **Acadian Orogeny** – major intensive tectonic event, intense collision deformed and metamorphosed the rocks of the White Mountains. Shallow subduction. Most of the deformation in the White Mountains occurred during the Acadian Orogeny Maximum metamorphism at 400 Ma Maximum elevation of ancient *White Mountains* during Acadian Orogeny was about 5000 m above sea level (p.72). What we have left is Mt. Washington at 1219 m elevation, the eroded roots of a formerly tall mountain – good for studying insides of a mountain **Neoacadian Orogeny –** "mild mountain building" Around 310 Ma Laurasia fused with Gondwana – a major step toward Pangea
335-175	**Pangaea aggregated as a supercontinent** from earlier continental units beginning around 335 Ma (Early Carboniferous) and persisted for about 160 million years until its breakup at 175 Ma (Middle Jurassic)
298-252	**Permian** **Alleghanian Orogeny** – Gondwana collided with most other landmasses to form the mature Pangean supercontinent with *Central Pangean Mountains* comparable in elevation to the present Himalayas at more than 8000 m. For White Mountains, the event was "a glancing blow" but with major consequences.
252-201 252	**Triassic** **Pre-Pangea supercontinent disaggregation completed.** **Siberia fused with Pangea to complete the assembly of the new supercontinent.**

Chapters 3B and 4 do not add new items to the linear series of events that unfold in Chapter 3A, but instead are "sidebars" that focus on fine tuning the North Country formations introduced in Chapter 3A; therefore, their dates overlap with the dates in

Chapter 3A. Chapter 3B discusses the deposition of rocks that form the White Mountains bedrock geology in Ordovician, Silurian and Devonian periods, while Chapter 4 deals with the deformation and metamorphism of those formations during the Devonian period with special reference to the elevation of Mt. Washington. I touch only lightly on these chapters (see maps at Eusden's Team 2013:56, 59, 62, 73, 83 and 90).

Ch. 3B	***485-370 Ma. White Mountains bedrock geology***
485-443	**Ordovician** deposition
443-419	**Silurian** deposition
419-370	**Devonian** deposition
Ch. 4	***419-370 Ma. Acadian + Neoacadian Tectonism***
419-370	**Deformation and Metamorphism**

Chapter 5A deals with the disaggregation of Pangaea, the extrusion of the Central Atlantic Magmatic Province, and the End Triassic Extinction; 5B deals with the White Mountains Magma Series; and 5C barely touches on the New England – Quebec Magmatic Province.

Ch. 5A	***251-201 Ma: White Mountains Plutonic-Volcanic Suite (WMPVS)***
254-251	**Triassic-Jurassic boundary:** ***Pangea begins to break apart*** Pangaea stretched, faulted, fractured, rifted; lava flows, dikes …. Beginning of the end of the supercontinent.
201	Eusden's Team (2013:78) says: "The likely cause of rifting and breakup of Pangaea at 200 Ma was a superplume [mantle plume] centered under Pangaea's crustal plate." I believe this is one of only two references to mantle plumes by Eusden's Team. Their account of its relationships to the White Mountain batholith and the breakup of Pangaea is unclear to me.
201-200	Volcanic eruptions located in the Central Atlantic region occurred about 201 Ma in four pulses lasting over ~600,000 years. Linked to the End Triassic Extinction and the opening of the Atlantic Ocean (2013:77), they yielded the Central Atlantic Magmatic Province (CAMP), one of the largest volcanic continental flood basalt events in Earth's history.
Ch. 5B	***201-150 Ma: White Mountains Magma Series (WMMS)***
201-145	**Jurassic rocks** Eusden's Team (2013: 79-82, 84) uses a multi-stage model of caldera collapse to describe an intense period of magmatism and volcanism during the Jurassic. Basalt ring dikes in the White Mountains provide examples.
Ch.5C	***150-100 Ma: New England – Quebec Magmatic Province (NEQMP)***
130- 100	**Cretaceous rocks** It appears that Mt. Washington and the Presidentials were in place and completed before or during this period and had entered a long decline into erosion. Eusden's team refers to renewed activity after a quiet period between 165-130 Ma, but mentions intrusions only as the result of Newfoundland separating from points further east (2013:84). Further Cretaceous developments are ascribed to the disaggregation of Pangea (2013:85).

Chapter 6 brings Eusden's Team's (2013) argument to a close.

Ch. 6	***100 Ma – present: Erosion, glaciation, uplift***
100-2.6	Eusden's Team (2013:87) says, "No rocks exposed in the White Mountains are younger than the 100 Ma to 130 Ma Early to Middle Cretaceous intrusions (i.e., the WMMS). … and …. [for this period] no record of geological activity is recorded except for the persistent erosion and gradual uplift of the land surface."
2.6 to Present	Ice Age. All the White Mountains experienced the same basic pattern of glaciation and erosion. Alternating glacial and interglacial periods were accompanied by major variations in types and intensities of erosion, changes in depth and weight of icesheets and glaciers, deformation and rebounding of impacted regions, etc.

Table 1. Historical timeline of the events that Eusden's Team (2013) described in Chapters 3 through 6.

Geological events that primarily impact rocks leave their marks on living organisms as well. As an anthropologist and a student of biological and cultural evolution, I am especially interested in the End Triassic Extinction event that occurred with the breakup of Pangaea at 201.3 Ma (Raup and Sepkoski 1982, Greshko 2019, Wikipedia 2022b). Although Eusden's Team (2013) mentioned it only briefly in Chapter 5A, it was a major bottleneck that impacted the evolution of most life forms, indirectly including our own. The geological event that opened the Mid-Atlantic Ridge and began the expansion of the Atlantic Ocean also destroyed 80% of Earth's known multicellular species. Among the 20% that survived, Jurassic dinosaurs were temporary winners.

Chapters 3, 4 and 6 are minimally problematic and receive no further discussion in this article. Chapter 5 deals with the disaggregation of Pangaea, the White Mountains Magma Series and the New England – Quebec Magmatic Province. They are more troubling, and I deal with them in the remainder of the article, frequently using visualizations to enhance my argument.

White Mountains Magma Series Within New Hampshire

Albert Einstein's (1950) revision of Occam's razor says, "Everything should be made as simple as possible, but no simpler". I suggest that over-simplifications in Chapters 5B and 5C are problematic.

Specifically, I suggest that Eusden's Team (2013) drew a metaphorical spatial boundary resembling the rectangular red boxes surrounding the physical White Mountains in Figures 3 and 4, pp.16-17. Those boxes either allowed or forced them to rule out some relevant data that was immediately available to them. Likewise, they put plate theory and plume theory into separate metaphorical boxes that allowed or forced them to rule out relevant linking ideas. I question these boxes.

It appears that Mt. Washington and the Presidentials stabilized between 200 Ma and 155 Ma and began their decline toward erosion and entropy. However, intense magmatism and volcanism associated with the Jurassic batholith and plutons occurred concurrently (Eby 1995). The White Mountains Magma Series (WMMS) or White Mountains Plutonic-Volcanic Suite (WMPVS) or White Mountain Igneous Province – three names for approximately the same spatially and temporally associated volcanic and plutonic rocks spanning the Jurassic period – took up residence near Mt. Washington and the Presidentials. In other words, between 200 Ma and 155 Ma, just as Mt Washington was going quiet for a while, plutons that together formed the White Mountains batholith were emplaced near its base.

In preparation for explaining their brief rejection of plume theory and acceptance of plate theory, Eusden's Team (2013:78) says, "Unlike the modern Hawaiian Islands which sit on oceanic crust, about 30 kilometers of continental crust lie below the volcanic complexes of the White Mountains but understanding the significance of this complication remains elusive." I suggest that the track of the proposed NEMP is vastly more complicated than the track of the Hawaiian-Emperor Seamounts, and that dismissing it as a "complication" is an over-simplification.

Despite superficial similarities between the Hawaiian–Emperor seamount chain and the WMMS, Eusden's Team (2013:78) says the Hawaiian mantle plume model does not apply to WMMS for the following reasons: "The WMMS do align but their ages are so variable in their distribution that such a simple explanation is inadequate. …. The very small volumes of basaltic rocks currently exposed, the small sizes of the magmatic centers, the abundance of granitic rocks of crustal origin suggest … rifting, not a mantle [plume]." The age and [spatial] distribution of the WMMS may record "80 Ma of global plate motions rather than motion relative to a hotspot." As an alternative to plume theory, Eusden's Team (2013:78-80) offers an analogy with a recent graphic from Norway that features caldera doming and plate tectonics. I discuss the matter below.

Partly to deal with these issues and their relationship to the proposed NEMP, Marple[9] et al (2018) recently collected, organized, graphically depicted in 33 figures, and very thoroughly documented a huge array of more-or-less raw data. Some is old data from previously published and unpublished sources, some is new data recently collected using new technology such as LIDAR, light detection and ranging technology that collects data otherwise hidden by water and vegetation. The title of their article is properly informative: "Ring-shaped morphological features … and their possible association with

[9] The authors include, Ronald T. Marple, James D. Hurd, and Robert J. Altamura. Henceforth I refer to them as "Marple's Team (2018)".

the New England hotspot track". I emphasize *possible*. What if the NEMP exists? What if it does not exist? How might these ring-shaped morphological features fit either scenario?

Figure 3 looks like a statement about the NEMP, but in fact it is a question. It provides a broadly focused view of the proposed NEMP and some of the diverse landscapes through which it might pass in Canada, New Hampshire and the Atlantic Ocean. It summarizes data, and relations among data, that we can interrogate seriously. The answers we derive may tell us a lot about NEMP, including the possibility that it does not exist. Although conclusions by Marple's Team (2018) are important, I am especially interested in their data, the exploratory experiments they conducted to acquire it, and the UPD procedures (described above in the Methods section), that they used to interpret their raw data and that I use in the following pages to understand their data.

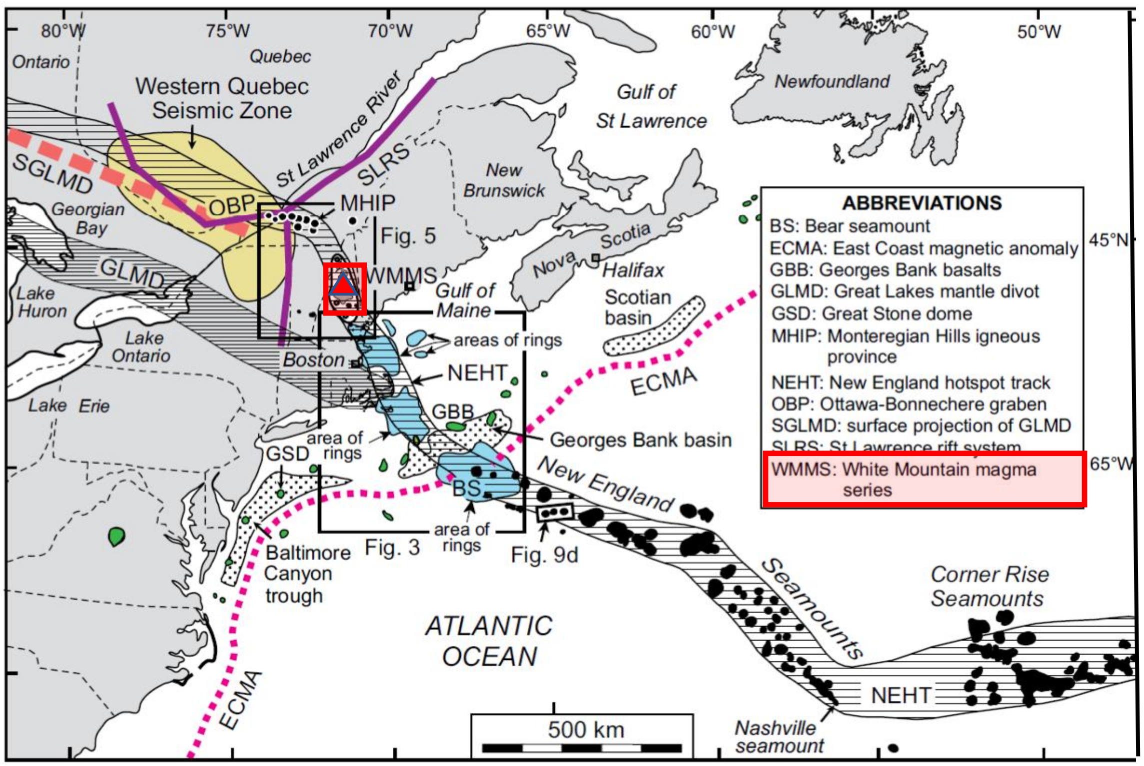


Figure 3 (Marple's Team 2018, Figure 1). This table summarizes the kinds of data the article by Marple's Team (2018) incorporates. **Striped** pattern shows the proposed path of the New England Hotspot Track **NEHT** or New England Mantle Plume **NEMP**. **Blue:** belts of ring-shaped morphological features. **Yellow:** Western Quebec seismic zone taken from Ma and Eaton (2007). **GLMD** (thin horizontally striped pattern) and **SGLMD** (thick orange dashed line) are from Rondenay et al. (2000) and Aktas and Eaton (2006). **Green:** igneous intrusions from Klitgord et al. (1988) plate 2C. The **Red box** is the region in New Hampshire where Eusden's Team (2013) focused their research.

To reduce the space used here, I have not repeated all the many citations of sources that are embedded in the captions of Figures 3 and 4. To check those citations, please consult the article by Marple's Team (2018).

Marple's Team worked specifically in the area beginning on Figure 3 at the Monteregian Hills Igneous Province (MHIP) in the northwest, continuing southeastward through the White Mountains Magma Series (WMMS) in the red box, and ending at the first cluster of peaks, including Bear Seamount, among the New England Seamounts (NES).

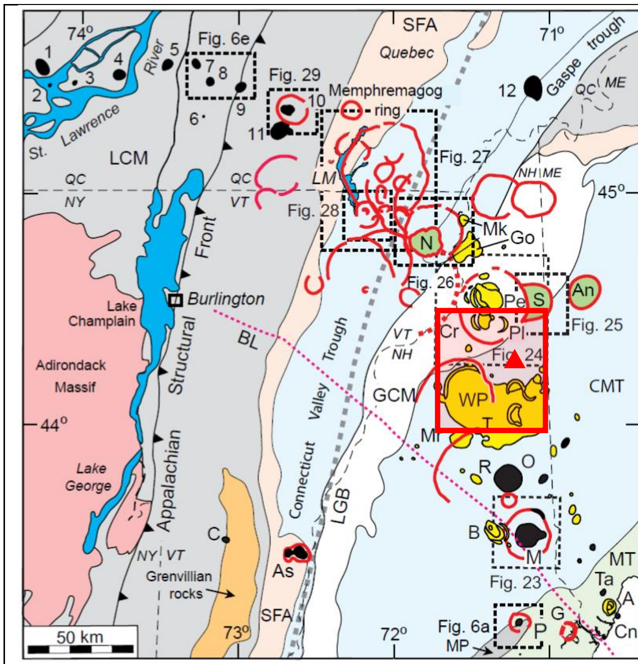


Figure 4 (Marple's Team 2018 Fig#5). Emphasizes the complexity of NH's volcanic landscape.
This caption pertains only to Figure 4.
Yellow: Jurassic intrusions 200-155 Ma.
Black: Cretaceous intrusions 130-100 Ma.

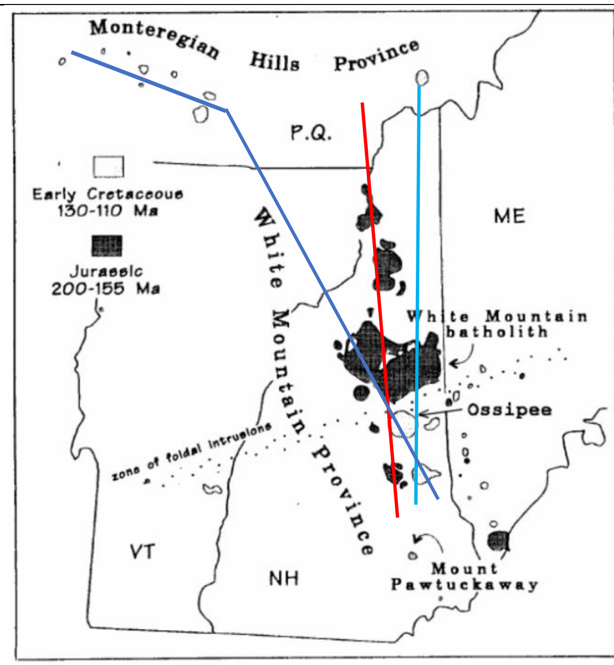


Figure 5 (Eby 1995 Fig#1). Emphasizes the clarity and simplicity of traditional datasets.
This caption pertains only to Figure 5**.**
Black Jurassic intrusions 200-155 Ma.
White: Cretaceous intrusions 130-100 Ma.

Features on land in NH, VT, NY, Quebec. Location map of the WMMS (White Mtns) and MHIP (Monteregian Hills). LGB (thick dashed grey line) is the eastern limit of the Grenville basement. Ring-shaped (curved) depressions interpreted herein are shown with red contours.
Igneous complexes: A, As, B, C, Cn, Go, M, Mk, Mr, O, P, Pe, Pl, R, Ta, and T are the Agamenticus, Ascutney, Belknap, Cuttingsville, Cape Neddick, Gore Mountain, Merrymeeting Lake, Monadnock, Mad River, Ossipee, Pawtuckaway, Percy, Pliny, Red Hill, Tatnic, and Tripyramid igneous complexes, respectively, and WP is the White Mountain pluton. G is the Great Bay ring-shaped depression.
Topographic basins: An, N, and S are, (cont→)

Andover, Nulhegan, and Success Hill basins. LM is Lake Memphrémagog. Cr (dashed curve) is an interpreted partial ring-shaped depression along a curved segment of the Connecticut River valley. The dashed line labeled BL is the Burlington lineament of McHone and Shake (1992).
Geologic units modified from Hibbard et al. (2006): CMT (Central Maine trough), GCM (Ganderian continental margin rocks), LCM (Laurentian continental margin rocks), MP (Massabesic pluton), MT (Merrimack trough), SFA (Shelburne Falls, other Laurentian affinities)
Monteregian Hills numbered from 1-12 are: 1-Oka, 2-Cadieux, 3-Bizard, 4-Royal, 5-St Bruno, 6-St Gregoire, 7-St Hilaire, 8-Rougemont, 9-Yamaska, 10-Shefford, 11-Brome, 12-Megantic.

Temporal alignment of Jurassic and Cretaceous plutons.

Table 2 lists all igneous complexes in Figure 4. I show them in the physical order in which they appear from top to bottom in the graphic, focusing on the area within New Hampshire that immediately surrounds the White Mountains.

Id#	Code	Yellow 200-155 Ma Black 130-100 Ma	Loc	Age in Ma				Comments
				200	**130**	**other**		
1.01	Mk	Monadnock	NH	**200**				
1.02	Go	Gore Mountain	NH	**200**				
1.03	N	Nulhegan Basin	VT			380		
1.04	DK	1 tiny dot	NH	**200**				
1.05	Pe	Percy	NH	**200**				
1.06	Pl	Pliny	NH	**200**				
1.07	DK	1 tiny dot	NH	**200**				
1.08	WP	White Mtn Pluton	NH	**200**				
1.09	TP	Tripyramid	NH		**130**			
1.10	T	Tatnic	NH	**200**				
1.11	MR	Mad River	NH	**200**				
1.12	R	Red Hill	NH	**200**				
1.13	O	Ossipee Ring Dike	NH		**130**			
1.14	DK	4 tiny dots	NH	**200**				
1.15	DK	4 tiny dots	ME					
1.16	B	Belknap	NH	**200**	**130**			
1.17	M	Merrymeeting Lake	NH		**130**			
1.18	DK	3 tiny dots	NH		**130**			
1.19	C	Cuttingsville	VT		**130**			
1.20	As	Ascutney	VT		**130**			
1.21	A	Mt. Agamenticus	ME			216		
1.22	P	Pawtuckaway	NH		**130**			
1.23	MP	Massabesic pluton	NH			625		
1.24	A	Agamenticus	NH	**200**				
1.25	Seb	Sebago pluton	ME			325		

Table 2. Translation of Figure 4 from its original graphic format to a more useful numerical format. Sorted vertically by Id# **-** hence by physical order on the ground – and horizontally by age in Ma.

Table 2 shows older Jurassic 200-155 Ma intrusions located farther north on the ground than younger Cretaceous 130-100 Ma intrusions as shown in Figures 4 and 5. Minimally, this argues against conflating these two distinctly different events.

The second point is more complicated due to incompatibilities between the maps: please pay careful attention to names and dates and do not let the colors confuse you. In Figure 5, the older Jurassic 200-155 Ma items appear as a freestanding group of black points that begin and end in that Figure. However, in Figure 4, the younger Cretaceous 130-100 Ma items including Ossipee, Pawtuckaway and many others appear as part of a long-term process that begins and ends beyond the north and south boundaries of New Hampshire. The upper extension connects with the Monteregian Hills to the northwest in Canada on the same map, but the lower extension connects with the New England Seamounts in the Atlantic Ocean on Figure 3. In other words, these data suggest that the Jurassic 200-155 Ma items are a stationary plate event isolated within Figure 5, while the Cretaceous 130-100 Ma items connect smoothly with Figure 3's Monteregian data to the north and seamount data to the south. This relationship yields a consistent but imperfect age progression that suggests the Cretaceous 130-100 Ma feature could be a plume event.

Spatial alignment of Jurassic and Cretaceous plutons.

In Figure 5, Eby's (1995) map shows the batholith and smaller plutons aligned from north to south in a ragged sort of formation. If we disregard ages and color coding on the map, it is possible to see a single collection of these intrusions in a ragged vertical column. On the other hand, if we pay attention to ages and color codes, it is possible to see the Jurassic plutons in a red line trending north and south from the White Mountain batholith, while the Cretaceous plutons form either of two blue lines. The light one goes straight north to Mt. Megantic, the dark one goes diagonally toward the main body of the MHIP. In either case the Cretaceous plutons are separated significantly from the Jurassic plutons.

In other words, the Cretaceous plutons are not only younger than the Jurassic plutons, but also, they are emplaced away from the Jurassic collection, dark blue to the west or light blue to the east. Disregarding the spatial alignment results in further conflation of the 200-155 Ma and the 130-100 Ma datasets. Paying due attention to the details displays two dimensions – temporal in Table 2 and spatial in Figure 5 – in which these are distinctly different datasets. If this is true, as I believe it is, it supports a conjecture that the Jurassic dataset may be a plate event, and the Cretaceous dataset a plume event.

Ring-shaped morphological features: caldera and ring dikes in New Hampshire.

Eusden's Team (2013:78-79) makes an analogy between caldera doming in the White Mountains and in Carboniferous and Permian (359-251 Ma) mountains of Norway, featuring a recent 5-stage model by Ramberg et al. (2008:293-95). They say: "The most striking feature of the WMMS is the … ring shaped intrusions that partially or completely surround the magmatic centers. These ring dikes are a key to understanding the emplacement of the WMMS central magmatic complexes." His argument, which focuses strictly on dikes surrounding magmatic centers, describes what seems to be a plausible mechanism that is compatible with plate theory. His discussion of these matters is phrased in general terms and does not specify whether the intrusions in question belong to the 200-155 Ma or 130-100 Ma series which implicitly conflates the two datasets.

Having accounted for the processes underlying caldera and ring dikes, Eusden's Team (2013:77-80) described two (or maybe three) ring dike complexes in Figure 2 that formed in the Franconia and Crawford regions about 192 to 186 Ma, four that formed in the Conway region about 175 Ma – all in the 200-155 Ma series – plus two smaller ones at Hart Ledge and Mt. Carrigain near the center of the White Mountains Batholith, and another one (or maybe two) in the Pliny and Pilot Ranges west of Berlin, New Hampshire.

Eusden's Team's (2013:77-80) narrow discussion of calderas contrasts with Marple's Team's (2018:232-250) broader discussion of ring-shaped morphological features in Figure 4, including offshore and onshore representatives of several categories of ring structures listed in Appendix E (Eppelbaum 2008). Here I omit the large array of inaccessible offshore data and focus on the more accessible onshore data including a host of features that Eusden's Team (2013) disregarded but Marple's Team (2018) considered, including Ossipee, Pawtuckaway and other ring dikes that belong to the Cretaceous 130-100 Ma series.

Heavy reliance by Marple's Team (2018) on a large quantity of diverse data collected in the past by equally diverse scientists stands in sharp contrast to arguments by others who have focused on one or another specific kind of data that may be insufficient to rule out almost anything. Work by Marple's Team (2018) does not confirm that the NEMP lives up to all expectations, but it does provide much circumstantial evidence from a more-or-less neutral source in support of its historical veracity. Their failure to confirm or deny the existence of the NEMP, given the scope and depth of the relevant data, means that tentatively accepting Eusden's Team's (2013) plate theory for one dataset is an entirely plausible option. But it also means that tentatively accepting Marple's Team's (2018) plume theory for the other dataset is equally plausible.

In this context I hope to reconcile Marple's Team (2018) with Euston's Team (2013) or vice versa. I suggest that Eusden's Team is free to claim a plate-based solution for the bounded package of 200-155 Ma ring dikes, while Marple's team is free to claim a plume-based solution for the temporally and spatially unbounded 130-100 Ma Monteregian Hills and New England Seamounts.

The bottom line to this point is that Mt. Washington and the Presidential Range are rooted securely in the Appalachian orogen, that the 200-155 Ma WMMS is rooted somewhat less securely in plate theory as Euston's Team (2013) argues, and the 130-100 Ma NEQMP is rooted equally tentatively in the NEMP as Marple's Team (2018) suggests. The obvious question that leaps out immediately is: What might account for the physical emergence of these three different mountains –three different "kinds" of mountains – in precisely the same spot?

I do not phrase the problem and its possible solution in terms of either-or, but rather in terms of both-and, teamwork, cooperation. The objective is not to rule out one or another proposed solution but to understand how this division of labor makes the task of hypothetical mountain building more manageable. By proposing this cooperative division of labor, I am vulnerable to opposition by plate advocates and plume advocates alike, with no obvious support from a third party.

New England – Quebec Magmatic Province

The NEQMP apparently became established as a local phenomenon between 130 and 100 Ma. If it is a segment of the NEMP track, then it constitutes part of the environment within which the proposed NEMP has operated for at least 200 Ma. A successful attempt to understand the complexities of the proposed mantle plume's behavior throughout that long history presupposes knowing a good bit about the highly diverse nature of Earth's crust at – and between – the points in space and time where the plume has manifested itself. I lack the skills required to analyze the plume theoretically, especially regarding possible variations in its temperature and power through time, but I shall offer suggestions about the context, south and north of New Hampshire, in which it may have operated. I suggest that the problem is not just to *analyze* conspicuous dots on the NEMP track but rather to *connect* the dots across the empty spaces where dots are absent.

South of New Hampshire

Many members of the southern segment of the NEMP track are known collectively as the New England Seamounts (NES). They include the nearby New England Seamounts *per se*, the Corner Rise Seamounts at an intermediate distance to the east, and possibly the remote Great Meteor Guyot on the African tectonic plate. Here I attempt to lay a foundation for a comprehensive statistical description of these ocean features so that informative patterns can be detected using unsupervised pattern detection procedures. So far much of the data seems to be nonexistent, unpublished or locked behind firewalls.

New England and Corner Rise seamounts

Figure 6 depicts the field of extinct volcanoes that comprise the New England and Corner Rise Seamounts (Google Earth 2022). If I seem to exaggerate the importance of the seamounts in the following paragraphs, it is because several published descriptions of them and their relationship to the proposed NEMP track accidentally or deliberately trivialize them. Several of the individual seamounts have been studied in some detail by life science research expeditions (NOAA 2022) but I have been unable to find a summary description of the whole. To see the seamount field from a useful perspective, I begin by noting that the outlined area in Figure 6 covers roughly 296,000 km^2 which is 33 times larger than the 8909 km^2 area of the White Mountains.

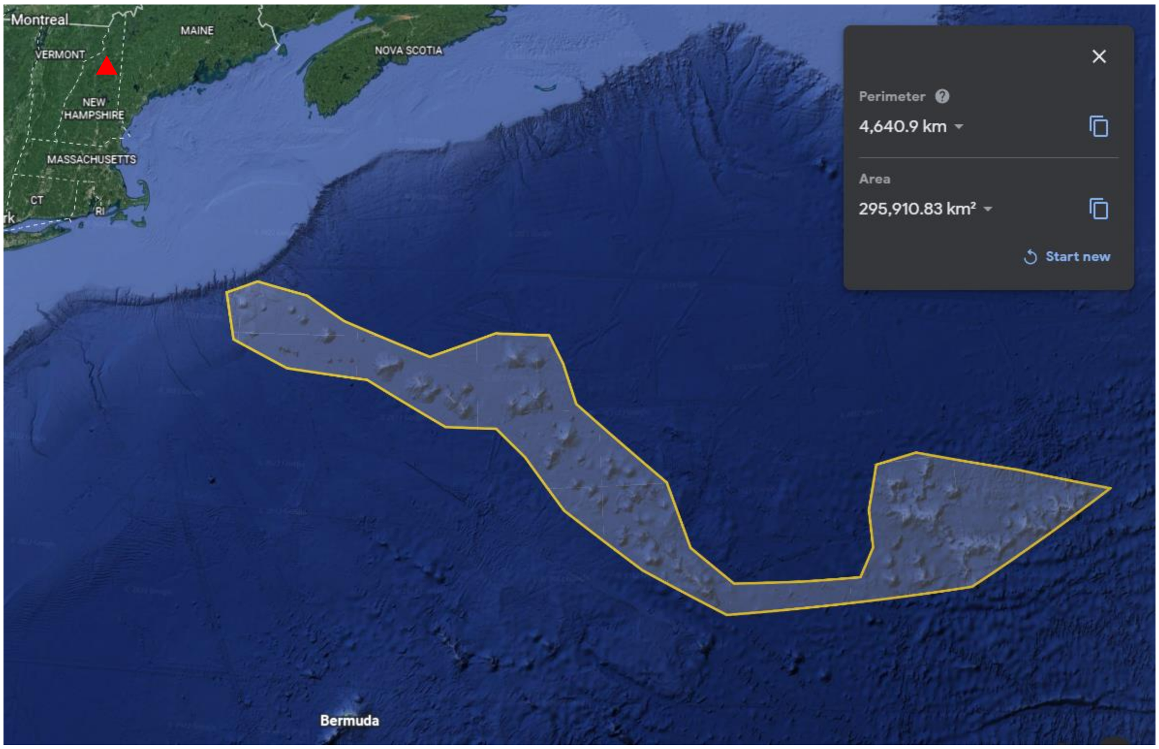


Figure 6. About 85 major and countless minor New England and Corner Rise seamounts spread over about 2000 linear km or 296,000 km^2 of abyssal plain (Google Earth 2022).

Marple's Team's (2018) data concerning ring-shaped morphological features on the continental shelf is rich and diverse, and they conclude that those features constitute evidence in support of plume theory. But also, it shows that the first incipient seamounts appear on the down slope beyond the edge of the shelf and that Bear Seamount, the first member of the real seamount range, appears near the base of the slope. Although seamounts do not poke up through the continental shelf, the ring-shaped morphological features on the shelf may, like the Emperor Seamounts that trail the Hawaiian Islands for thousands of kilometers, offer evidence of the proposed NEMP.

At the edge of the continental shelf in Figures 3, 6 and 9, at a depth of about 100 m, the ocean floor plumets to a depth of about 1000 m then tapers to a more-or-less constant depth of about 5000 m that it maintains for hundreds of km toward the southeast

(NOAA/Watling 2003, USA.FisherMap.org) before rising toward the mid-Atlantic Ridge. This is the setting occupied by the seamounts.

The seamounts begin about 400 km east of Boston, just beyond the edge of the continental shelf, and stretch an additional 2000 km in an L-shaped pattern eastward from the coast of New England (Google Earth 2021), about ten times the 200 km distance between Boston and Mt. Washington. The two groups together have more than 85 major peaks (Shank 2010). Summit elevations above the ocean floor range from 400 m to more than 5000 m but do not achieve the elevation of the continental shelf. In approximately descending order from the west, New England Seamount ages are 100 to 83 Ma and Corner Rise Seamount ages are 80 to 76 Ma (NOAA/Watling 2003). By not considering the seamounts in conjunction with the White Mountains, Eusden et al (2013) safely said, "no record of geological activity is recorded except for the persistent erosion and gradual uplift of the land surface" [between 100 Ma and 2.6 Ma].

Submarine peaks with elevations exceeding 4000 m from the seabed put Mt. Washington's much lower elevation of 1219 m above sea level in proper perspective. One possible impression to gain from looking at Figure 6 and comparable representations of the seamounts is that they are tiny, insignificant debris scattered on the seabed. This false impression appears to rest on a cultural "prejudice or attitude of bias in favour of the interests of members of one's own [group] and against those of members of other [groups]"; i.e., it is a generalized form of speciesism, a term coined and defined by Ryder (1970) and popularized by Singer (1975). By any reasonable standard these seamount fields make the White Mountains of New England appear to be inconsequential, not the other way around.

Table 3 lists seamounts within the New England and Corner Rise Seamount ranges. To this point in time, 20 March 2022, my attempts to access usable statistical data for Table 3 have been uniformly unsuccessful. Latitude and longitude data for New England seamounts are from *Marine Gazetteer Placedetails* (2017). Distances are measured in the metric system but often are missing and unreliable. With minor exceptions the table is sorted by latitude.

Id#	New England Seamounts	Summit elevation above sea floor	Summit depth below sea level	Distance from New England coast	Surface area	Max age Ma	Long. N	Lat. W	Notes
2.01	Bear	1102	1104	Western		103	39°55′	67°24′	
2.02	Physalia	1,848	1891				39°48′18"	66°52′45″	
2.03	Retriever	1,819	2201				39°47′37″	66°14′41″	
2.04	Mytilus	2,269	2430				39°21′37″	67°8′48″	
2.05	Picket		2308				39°38′10″	65°58′52″	
2.06	Balanus	1,469	1711				39°22′58″	65°22′47″	
2.07	Asterias		3409				38°53′56″	65°17′59″	

2.08	Kiwi		3885				39°19′6."	64°31′21″	Error
2.09a	Kelvin-a	3425	1757				39°19′6″	64°31′21″	Error
2.09b	Kelvin-b	3208					n/a	n/a	
2.09a	Atlantis II	1,645	2920				n/a	n/a	
2.10	Panulirus						38°28′1"	64°47′11″	
2.11	Sheldrake		2574				38°26′29″	62°5′9"	
2.12	Gosnold	3350	1640	730	3780	90	38°6′55″	62°15′54″	Sowers 2020
2.13	Gregg	893	987				n/a	n/a	
2.14	San Pablo	1,093					38°56′23″	60°27′25″	
2.15	Manning	3,519	1,504				38°9′54″	60°40′0″	
2.16	Vogel						37°13′41″	60°14′48″	
2.17	Rehoboth	1,217					37°32′5″	59°55′59″	
2.18	Allegheny						36°52′7″	58°44′16″	
2.19	Michael						36°21′56.6″	58°21′2″	
2.20	Gredo						n/a	n/a	
2.21	Gilliss						n/a	n/a	
2.22	Nashville	1,975		Eastern		83	34°59′59″	57°21′3″	
2.99	Buell						39°3′46″	66°24′0″	
2.99	Gerda						36°14′13″	57°29′56″	
2.99	Hodgson						35°34′56″	58°40′0″	

Id#	Corner Rise Seamounts . Peaks	Summit elevation above sea floor	Summit depth below sea level	Distance from New England coast	Surf-ace area	Max age ma	Long. N	Lat. W	Notes
3.01	Bean								
3.02	Caloosahatchee						34.65	49.65	
3.03	. Milne-Edwards								
3.04	. Verrill Peak								
3.05	Castle Rock								
3.06	Corner								
3.07	. Goode Peak								
3.08	. Kükenthal								
3.09	Justus								
3.10	MacGregor								
3.11	Rockaway								
3.12	Yakutat						35º15'00"	48° 0' 0"	

Table 3. Named seamounts within the New England and Corner Rise Seamount ranges.

The upper part of Table 3 lists a sample of seamounts within the New England Seamount chain while the lower part lists a comparable sample within the Corner Rise Seamount chain. Their Id# codes increment from west to east. Table 3 is a rough outline for a catalog of names and statistics of these seamounts. Tabular data for seamounts are highly elusive. Readily accessible datasets on the web would be useful.

Great Meteor Guyot

Figure 7 represents guyot in general, but its proportions differ from those of the Great Meteor which is 4,500 m high and has a summit area of about 52x28=1465 km^2. The crust underlying it is dated at 85 Ma, and radiometric dating of the surface yields dates of

11, 16 and 22 Ma. Its top surface is approximately 270 m below sea level. (Mohn 2010) See footnote #4 for other details.

This guyot is a member of the Seewarte (German: "naval observatory") Seamount Chain whose existence has been attributed widely to its passage over the NEMP. The Chain is part of the Azores archipelago and the Azores Triple Junction where the North American, Eurasian and African tectonic plates intersect (Luis, Miranda, Galdeano et al 1994). Also, it is adjacent to the Mid-Atlantic Ridge. Furthermore, Great Meteor Guyot often is mentioned in conjunction with Ilha de Santo Antao in the Cape Verde Islands which has been attributed to a mantle plume whose track resembles that of NEMP (Zurevinski 2008).

In other words, understanding the tangled structures and events, past and present, associated with the Great Meteor Guyot is challenging, especially considering Koppers et al (2021a:382) cautionary tale at the beginning of this article. I suggest that making bold assertions concerning genetic connections between Great Meteor and points west on the NEMP track is more than risky.

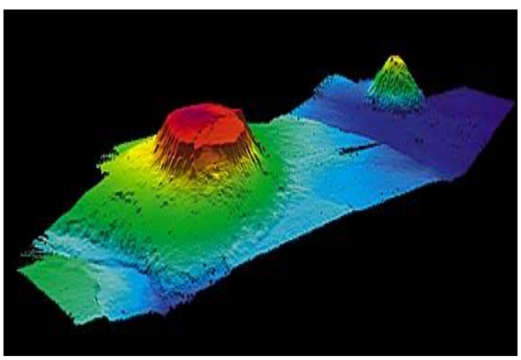


Figure 7. A severely truncated representation of the 4500 m Great Meteor Guyot (3-D depiction of Bear Seamount, with Physalia Seamount in the background: NOAA 2013, Wikimedia Commons, public domain.)

Figure 8. Left-center: Mid-Atlantic Ridge, Azores Triple Junction (NoAm, Eur, Afr plates), Seewarte Seamount Chain to southeast, Great Meteor Guyot third from the bottom of the chain. Cape Verde beyond the bottom right corner. (Image by Google Earth 2021; enlarge to view full screen.)

Nevertheless, since the guyot may belong to the mantle plume track it should be in the list for it has a great deal to offer by way of diversity as a huge example of a special kind of seamount.

The base map for Figure 9 is an excerpt from the famous *The World Ocean Floor Map* by Marie Tharp and her colleagues at the Lamont-Doherty Geological Observatory Earth Institute (Tharp, Heezen and Berann 1977). The figure shows the approximate locations of major segments of the proposed NEMP track south of Mt. Washington, across the continental shelf that has no seamounts, across the abyssal plain with the New England

and Corner Rise seamounts whose maximum elevations do not exceed the elevation of the continental shelf, across the mid-Atlantic Ridge which not surprisingly shows no visible signs of the proposed mantle plume, apparently ending with the Great Meteor Guyot in its marvelously complex setting.

Much of the data systematized by Marple's Team (2018) has been available for many years. Eusden's Team (2013) selectively used some relevant land-based items but no submarine items. At this point I am not concerned with a detailed analysis of these items, but I am eager to significantly increase their visibility. If the mantle plume track and not just the mantle plume itself is of importance, we must pay approximately equal attention to where it did - and where it did not - leave its track.

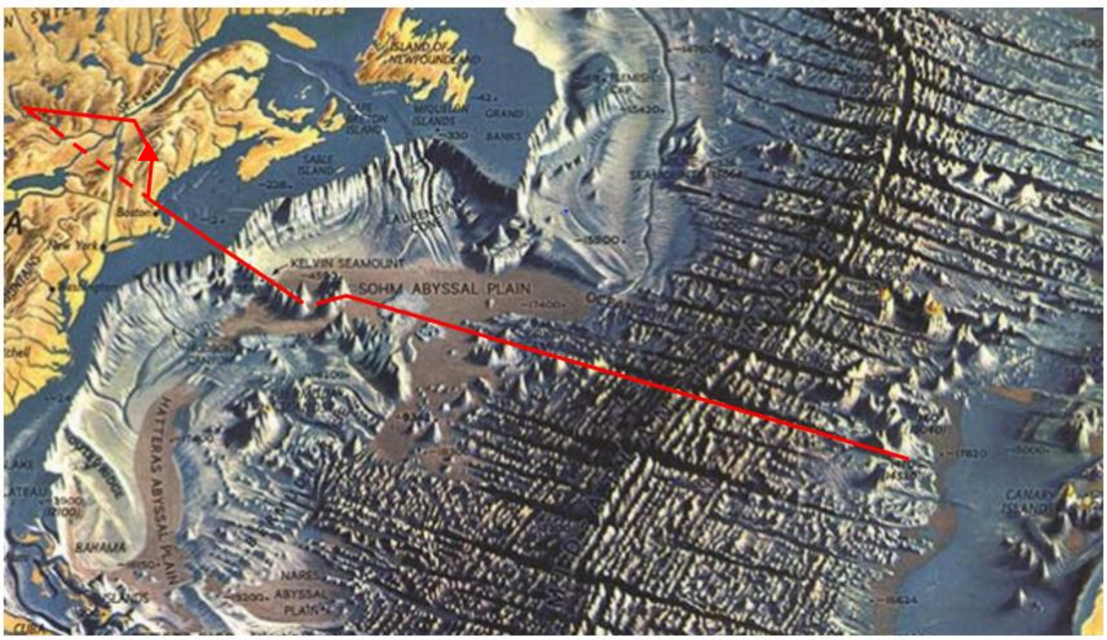


Figure 9. Approximate route of major submarine segments of the proposed NEHT. This illustration is based on Heinrich C. Berann's supplement to the June 1968 issue of the *National Geographic Magazine*. (Tharp, Heezen and Berann 1977).

I have found multiple publications that link the Great Meteor Seamount to the NEMP by way of circular arguments, but I have not found even one that does NOT use the logical fallacy of circular reasoning. My search has been discouraging.

North of New Hampshire.

Again, I attempt to lay a foundation for a comprehensive statistical description of selected geological features so that informative patterns may be detected using unsupervised pattern detection procedures, and again the data are sketchy. Except for that shared problem, the northern and southern extensions of the proposed NEMP are quite different from each other.

Monteregian Hills

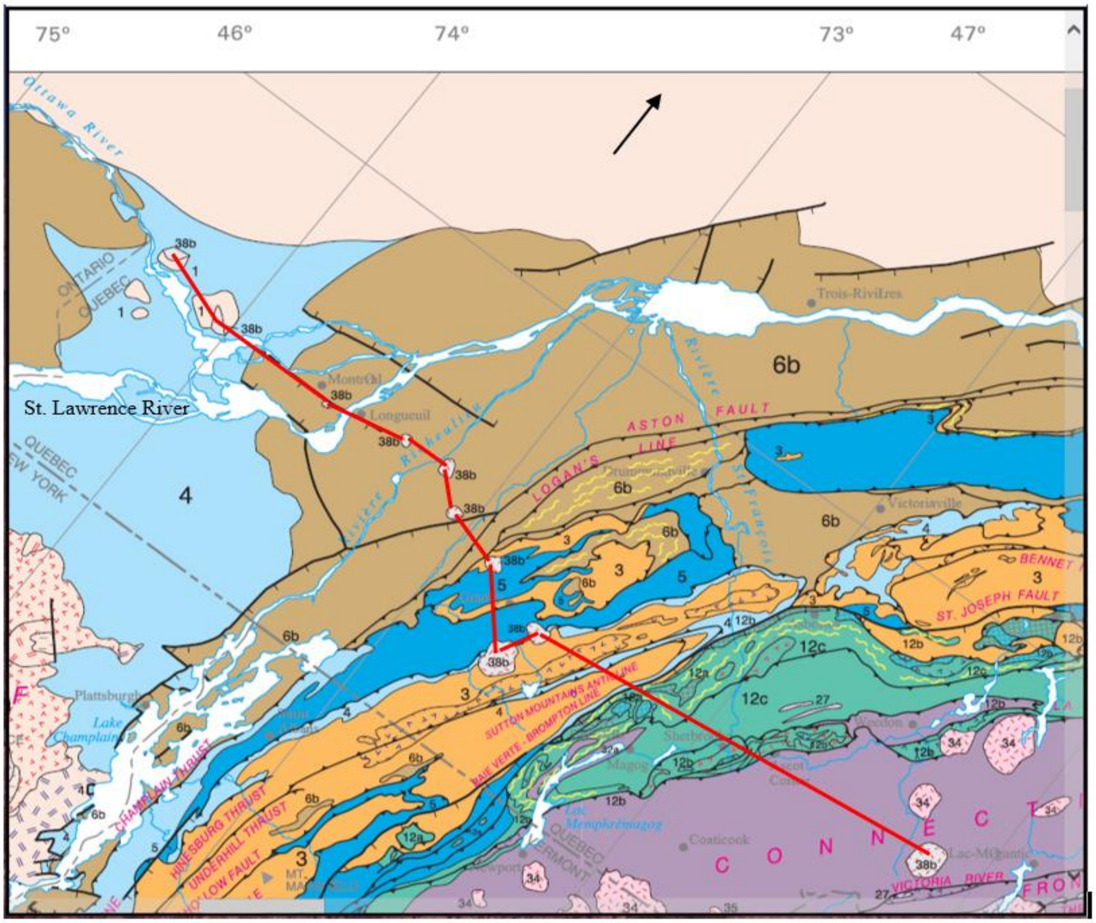


Figure 10. Location of the Monteregian Hills Igneous Province (MHIP) on Hibbard et al. (2006)

Figure 10 shows the MHIP in Quebec on the beautiful *Tectonic Lithofacies Map of the Appalachian Orogen* by Hibbard et al. (2006). Inflections at points labeled 38b on the red line represent a group of plutons in an irregular west-east line a few kilometers north of the US border, northwest of the White Mountains and aligned with the proposed NEMP. Each hill, about 200 to 500 meters high with the appearance of a monadnock, is an erosional remnant of intrusive volcanic rocks that have resisted weathering longer than surrounding sedimentary rocks. Notice the direction of the north-pointing arrow at the top of the Figure.

The hills of the MHIP that are north of the St. Lawrence River on this map are just barely on the Canadian Shield which ends near the river. (Since I am not concerned with alphanumeric codes, I have omitted the key.) This part of the Grenville province constitutes the youngest portion of the Canadian Shield.

Counting hills should be a straightforward operation, but in this case it is not. Minimally, at the beginning of the 20th century, the Monteregian Hills consisted of 8 hills (Adams 1903:240). Sometime around mid-century the count increased to 10. Later in the century, it increased to 12. Now Table 4 lists 12 intrusions in my 4.00-series, and at least 5 others in my 5.00-series.

Eby (1984) reported the MHIP intrusions in the 4.00-series of Table 4 fell into two age groups, one group with minimum and maximum age ranges between 130 and 140 Ma, the other group with min-max age ranges between 118 and 122 Ma, with no overlap between them. An alternative way to view this matter, using current data that I assembled from diverse sources, says that the whole population has maximum ages ranging from 130 to 138 Ma, and minimum ages ranging from 118 to 128 Ma. Regardless of how they are measured, these estimated maximum and minimum ages do not change precisely and systematically from west to east, but their ages are quite close to each other. Concerning such approximate measurements, Voltaire's (1764) aphorism, "the best is the enemy of the good", applies here[10]. Likewise, there is an irregular but nonetheless real increase in the elevation of the 4.00-series Hills from west to east. Is it of any significance? The 5.00-series intrusions seem to be undated.

If the Monteregian Hills in Quebec are indeed constituents of the NEMP track, I suggest that the 130-100 Ma intrusions in the White Mountains passed under the 200-155 Ma intrusions and continued their passage to the sea, unencumbered by the older items; i.e., that the 200-155 Ma batholith and plutons are explainable by plate theory and that the 130-100 Ma intrusions are explainable by plume theory.

Introduction to volcanic pipes, diatremes and kimberlite pipes

Perhaps the most interesting intrusions in Table 4 are Id 4.03 and 5.01-5.05**.** The surrounding Monteregian Hills have plutons at their cores, but Ile Bizard and members of the Oka complex are different. Here we encounter a family of inverted cone-shaped structures variously called volcanic pipes, diatremes and kimberlite pipes. They are subterranean geological structures formed by violent, supersonic eruptions of deep-origin volcanoes. Their diameters generally are small - in the range of meters to tens-of-meters - while their depths are great - in the range of many hundreds of kilometers. They often

[10] Voltaire's aphorism is one of many useful versions of the warning against counterproductive perfectionism expressed in other words by Montesquieu, Shakespeare, Aristotle, Confucius and 20th century scientists, economists and software engineers.

conduct diamonds mixed with fragmented rocks called kimberlites from great depths to the surface.

Id#	Intrusion names. Adams 1903 +	Type	Height	Max age in Ma	Min age in Ma	Long. N	Lat. W	Comments
4.01	Oka Hills	Pl	249 metres (817 ft)	n/a	n/a	45°27'53"	74°04'21"	Normally polarized; ring dikes
4.02	L'Île-Cadieux	Pl	n/a	n/a	n/a	45°25'54	74°01'00	Normally polarized
4.03	Ile Bizard	Di	15 m knoll 80 m intrusion	136	120	45°30'00"	73°53'25	Diamonds extracted 1968 Not a pluton?
4.04	Mount Royal	Pl	233 metres (764 ft)	138	118	45°30'18"	73°35'55"	Reversely polarized; great # of dikes occur – Adams 249
4.05	Mont Saint-Bruno	Pl	218 metres (715 ft)	136	118	45°33'01"	73°19'09"	Reversely polarized
4.06	Mont Saint-Grégoire (Alt name: Mt Johnson)	Pl	251 metres (823 ft)	n/a	119	45°22'33"	73°11'57"	Normally polarized
4.07	Mont Saint-Hilaire	Pl	411 metres (1,348 ft)	135	n/a	45°22'32"	73°09'11"	Reversely polarized, 377 minerals
4.08	Mont Rougemont	Pl	381 metres (1,250 ft)	137	n/a	45°28'35"	73°03'14"	Reversely polarized
4.09	Mont Yamaska	Pl	416 metres (1,365 ft)	n/a	120	45°27'26"	72°51'28"	Reversely polarized
4.10	Mont Shefford	Pl	526 metres (1,726 ft)	130	120	45°21'25"	72°35'46"	Reversely polarized
4.11	Mont Brome	Pl	553 metres (1,814 ft)	138	118	45°16'57"	72°37'58"	Reversely polarized
4.12	Mont Mégantic	Pl	1105 metres (3,625 ft)	133	128	45°25'42	71°09'14"	Reversely polarized[11]
Id#	**Intrusion names for the Ile Bizard region, Raeside and Helmstae 1982, 1983.**	**Type**	**Height**	**Max age in Ma**	**Min age in Ma**	**Long. N**	**Lat. W**	**Comments**
5.01	Carillon	Di	n/a	n/a	n/a	45°34'29"	74°22'36"	Normally polarized
5.02	Saint-André-Est	Di	130 metres (430 ft)	n/a	n/a	45°33'55"	74°18'40"	n/a
5.03	Ile Ste. Helene	Di	n/a	n/a	n/a	45°31'04"	73°32'11"	Normally polarized
5.04	Brilund	Di	n/a	n/a	n/a	45°	74°	Normally polarized
5.05	Ile Ste. Dorothee	Di	n/a	n/a	n/a	45°	74°	Reversely polarized

Table 4. Incomplete statistical data for Monteregian Hills. Pl = pluton; Di = diatreme, n/a = not available. Sorted by latitude with minor exceptions,

The cluster of small intrusions at Ile Bizard has been reported to contain diatremes (the pipes) and kimberlites (the rock fragments sometimes carrying diamonds) plus other closely related materials. A major part of the intrusion is an oval pipe-like body, 80 m long with a probable age of 126±6 Ma. Raeside and Helmstae (1982, 1983) used Figure 11 to argue in favor of diatremes and kimberlites and pointed to a small collection of diamonds reportedly found there in 1968, while Mitchell (1979) strongly opposed their position and argued that the diamonds were contaminants. Controversy raged for years.

[11] Foster and Symons (1979).

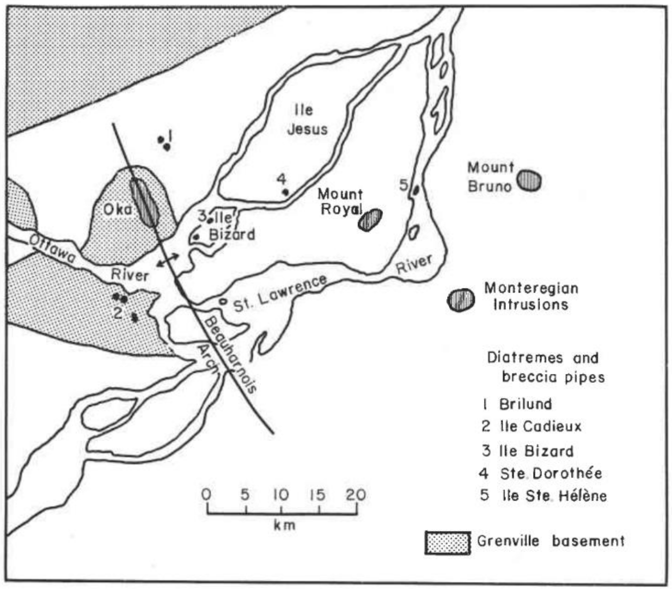


Figure 11. Generalized geological map of the Montreal area showing aspects of Monteregian igneous activity at the confluence of the Ottawa and St. Lawrence Rivers. This cluster includes Mont Royal, Mont Bruno and Oka as members of NHIP, plus 5 diatremes and other pipes including 3. Ile Bizard scattered among them, plus more that are not illustrated here (Raeside and Helmstae 1982).

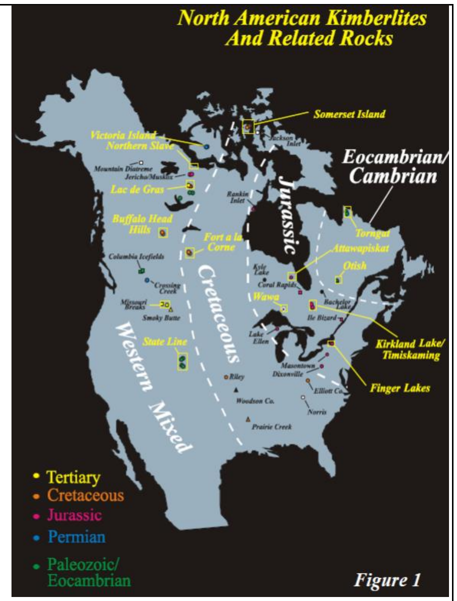


Figure 12. Ile Bizard appears in the Jurassic region (180-140 Ma) beside the St. Lawrence River (Heaman and Kjarsgaard 2003:2).

I find Raeside and Helmstae's (1982) map (Figure 11) of the confluence of the Ottawa and St. Lawrence Rivers at the edge of the Canadian Shield, plus Heaman and Kjarsgaard's (2003) map (Figure 12) of temporal and spatial emplacement provinces, plus Hibbard et al's (2006) map (Figure 10) of the MHIP to be more persuasive than Mitchell's (1979) contentious pronouncements. Also, some of Raeside and Helmstae's papers contain fine depictions of kimberlite pipes from the Ile Bizard cluster.

The possibility that the area around Oka and Ile Bizard has a small and perhaps poorly developed kimberlite field supports the further possibility that the larger kimberlite fields to the northwest of Montreal are encompassed by the NEMP track as others have argued. This controversial finding at Ile Bizard may or may not be trivial concerning NEMP and more remote kimberlite fields, but at least all these people talked to each other.

Kimberlite Fields and Large Igneous Provinces

Zurevinski et al. (2008) and others have linked the proposed NEMP to kimberlites northwest of the MHIP. Kimberlite fields are of interest here – not individual pipes or isolated diamond mines, but sprawling clusters containing perhaps hundreds of small, hard to find, kimberlite pipes, each possibly containing fortunes in diamonds. Kimberlite pipes and diamonds have a strong affinity for cratons of which the Canadian Shield is a prime example. If the area in the vicinity of Ile Bizard is indeed an incipient kimberlite field, then it is reasonable to suggest that it may serve as a metaphorical bridge between the MHIP and the kimberlite fields of Ontario, Nunavut and the Northwest Territories.

Kimberlite fields

To a limited extent I understand how mantle plumes relate to cratons under whose great pressure they form, and to Large Igneous Provinces and mass extinctions where they may be maximally destructive. But it is not clear to me how they relate to kimberlite fields. Are mantle plumes especially effective at creating, picking up, transporting or ejecting diamonds through kimberlite pipes enroute to the surface? Or do they damage or destroy diamonds enroute to the surface? What are the other alternatives?

Despite my limitations as a non-geologist, I suggest that the proposed beneficial correlation between mantle plumes and kimberlite pipes has some merit, and tentatively explore it. Figure 13 shows the distribution of kimberlite fields and operational diamond mines in Canada. Scott Smith (2008) published the figure and I superimposed it on a minimally legible copy of a physiographic map of Canada to show the extent to which kimberlite pipes tend to occur preferentially beneath cratons.

In Figure 13, the red lines describe alternate routes of the NEMP track in the Arctic region. It assumes initially that the track connects with the diamond mines at Kirkland Lake, Timiskaming, Victor Mine and Attawapiskat. Those linkages seem to be secure, and data for them appear below in Table 5.

But beyond Attawapiskat the route is much more problematic. Extrapolating from Heaman and Kjarsgaard (2003), it may follow an eastern track through the Churchill kimberlite field in Nunavut Territory (NU), that is supported by kimberlites at Rankin Inlet and Chesterfield Inlet dated from 225-170 ma (Zurevinski 2008/2011). This track goes due north to the High Arctic.

The Churchill kimberlites belong to the corridor of Jurassic kimberlite magmatism in Figure 12, which includes Kirkland Lake, Timiskaming, and Attawapiskat kimberlite fields (Heaman and Kjarsgaard 2003). Churchill kimberlites extend this corridor ~800 km northwest, suggesting that the corridor may continue further northwest with older kimberlites. Zurevinski et al. (2008) suggest that this corridor may be the continental expression of magmatism linked to one or more mantle-plume hotspot track(s), a pattern geographically coincident with independent estimates for the timing and location of the continental extension of both the Great Meteor and Cape Verde hotspot tracks.

Or it may follow a northwestern track through the Slave Craton kimberlite fields in Nunavut and the Northwest Territories. The northwestern track is supported by 500 or more kimberlite pipes in the Slave Craton kimberlite fields. Six huge kimberlite fields in that region date from 613 Ma to 45 Ma, and the Jericho field at 175-170 Ma seems to be the most likely kimberlite suspect (Heaman and Kjarsgaard 2003). This track continues northwest to Victoria Island.

Although there are hundreds of kimberlite pipes in this region (Heaman, Phillips and Pearson (2019) say >1000), only a handful of diamond minds are fully operational there. Figure 14 provides a solid mental image of a two-pipe diamond mine. This remarkable summertime satellite photograph shows the Diavik Diamond Mine in Slave Craton's Lac de Gras kimberlite field. The NASA Earth Observatory photo captures a fragment of the lake it which it is located. In addition to two main open pits, waste rock piles, and an airstrip (white strip at the top), the complex also houses processing plants, fuel tanks, water and sewage processing facilities, administrative buildings, and accommodations for workers and other residents.

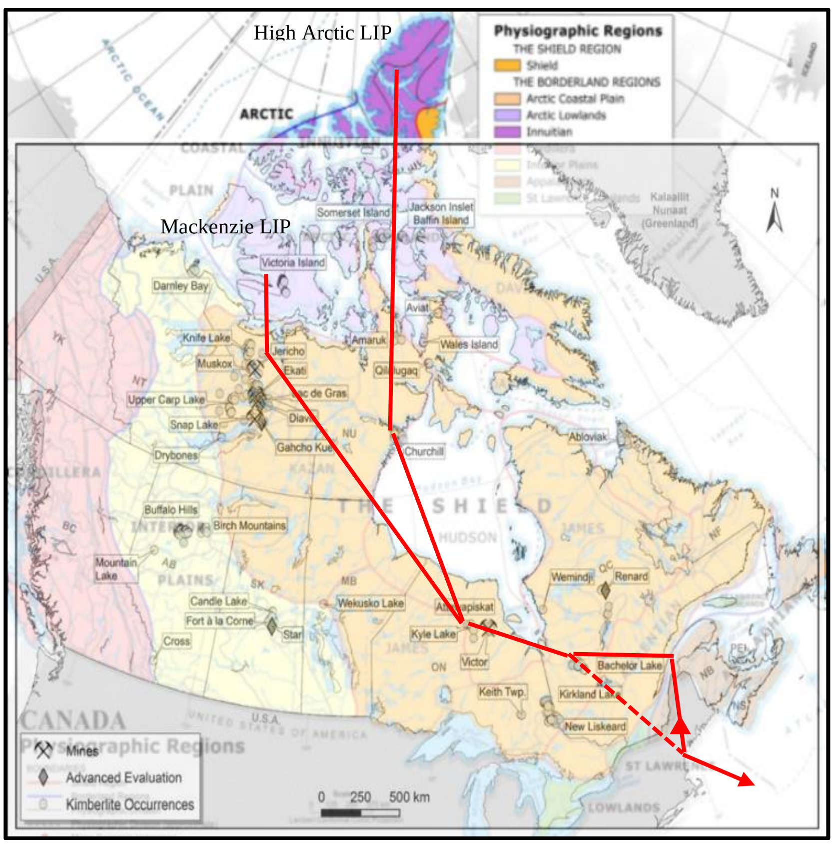


Figure 13. Base map is Canada Physio Regions Map (2006). Overlay is map of locations of kimberlite fields on the Canadian Shield. (Scott Smith 2008:10). Key: NT = Northwest Territories, NU = Nunavut, AB = Alberta, SK = Saskatchewan, ON = Ontario, QC = Quebec. Red lines represent alternative routes of the proposed NEMP track (see text), possibly originating at the Makenzie or High Arctic LIPs.

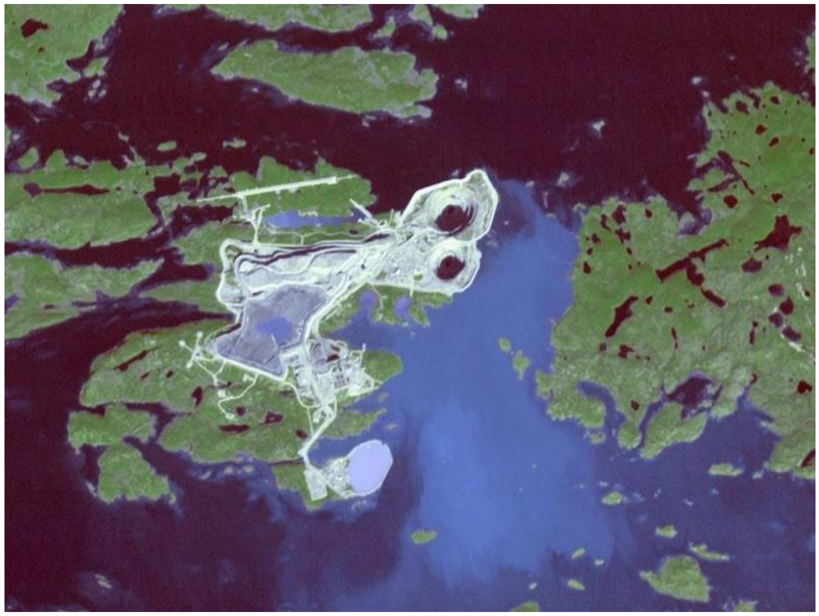


Figure 14. Diavik Diamond Mine located on a small island in the Lac de Gras kimberlite field, Northwest Territories, Canada. (NASA/METI/AIST/Japan Space Systems 2016: public domain).

Large Igneous Provinces (LIPs)

Earth history has been punctuated by geologically short duration events during which large volumes of magmas were generated and emplaced by processes unrelated to "normal" seafloor spreading and subduction. Evidence of the resulting Large Igneous Provinces[12] (LIPs) is preserved in diverse forms including continental flood basalts shown in Figure 15 and giant swarms of vertical dikes or horizontal sills which are sheets of rock that are formed in fractures in older rocks, forming deep-level plumbing systems as shown in Figures 16 and 17.

ID #	Prov	Names of kimberlite fields and mines	Age max in Ma	Age min in Ma	Long. N	Lat. W	Comments
		Large Igneous Provinces (LIP) (see next page)					
702	NU	Mackenzie giant radiating dike swarms, mantle plume / focal point on Victoria Island, LIP	1267		69°0'0"	112°0'0"	Approx lat/long of focal point
701	NU	HALIP, mantle plume	180	80	81°0'0"	70°0'0"	Approx lat/long of focal point

[12] Large Igneous Provinces (LIP): very large accumulations (>100,000 km^2) of igneous rocks that are erupted or emplaced at depth within <1 million years. Includes: continental flood basalts, dike swarms, sill provinces. Examples: Deccan Traps, Siberian Traps, Mackenzie Dike Swarms. Excludes: basalt sea floors, seamounts, other products of 'normal' plate tectonics. Associated with: Beginnings: mantle plumes; Endings: mass extinctions. Problem: How are such enormous volumes of basaltic magma formed and erupted over such short periods of time? See LIP-Com (2021).

		Slave Craton kimberlite fields Nunavut and Northwest Terr.					>400 pipes
601	NU	. Coronation Gulf – KF	613		68º08'	112º00	
602	NU	. Southern – KF	545	520			
603	NU	. Western – KF	460	430			
604	NU	. Jericho – mine	**175**	**170**	65°59'50"	111°28'30"	
605	NU	. Lac de Gras – KF	50	55			
606	NU	. Ekati – mine	62	45	64°42'49''	110°37'10''	Mindat.org
607	NU	. Diavik – mine	55		64°29'56"	110°14'19"	
		NW–SE corridor of Jurassic–Triassic kimberlite magmatism					**Data from Zurevinski, et al 2011**
501	NU	. Churchill – KF	**225**	**170**	63°15'01"	91°44'45"	79 intrusions
502	NU	. Rankin Inlet	**225**	**170**	62°48′35″	92°05′58″	Mantle plumes possibly:
503	NU	. Chesterfield Inlet			63°20′27″	90°42′22″	New England and Cape Verde
504	ON	. Attawapiskat – KF	180	150	52°55′21″	82°25′31″	18 kimberlite pipes, 16 w/ d
505	ON	. Victor – mine	170	n/a	52°49'14"	83°53'00"	2 adjacent pipes out of 18
506	ON	. Kirkland Lake – KF	165	152	48°10'54"	80°01'20"	No mining?
507	QC	. Timiskaming – KF	155	134	47°18'36"	79°29'03"	>50 pipes

Table 5. Incomplete data for possibly relevant kimberlite fields (KF), diamond mines and LIPs; NU – Nunavut; ON – Ontario; QC – Quebec; KF – kimberlite field. Based on part on Heaman and Kjarsgaard (2003) and various additional sources. Sorted by latitude with minor exceptions.

The High Arctic Large Igneous Province (HALIP) was distributed over the circumpolar Arctic Islands of Canada, northern Greenland, Svalbard, Franz Josef Land and adjacent regions of the Arctic Ocean (Buchan and Ernst 2006). The protracted event, which spanned the period of 180-80 Ma, appears to have been powered by a mantle plume with no name that sometimes is mentioned in conjunction with the proposed mantle plumes associated with the Iceland, New England, Great Meteor and Cape Verde mantle plumes. In any event, the proposed location of the plume was far north of the Churchill kimberlite field, the magnitude of the LIP seems to have been adequate for any task, and its timing seems to have been plausible. But the great distance may have been excessive.

The Mackenzie Continental Flood Basalt LIP (MLIP) was distributed over most of the Slave Craton and Nunavut (Ernst 2014) as shown in Figure 16. The mantle plume that appears to have powered it was located on or near Victoria Island, which is on the north side of Coronation Gulf, directly opposite the Slave Craton, adjacent to the northern edge of the Canadian Shield, and almost within sight of the Slave Craton kimberlite fields. Figure 17 is a representative example of the giant dike swarm depicted schematically in Figure 16. Kjarsgaard and Levinson's (2002) comprehensive and detailed textual and tabular history of Canadian diamonds places special emphasis on the 326 known kimberlite pipes on the Slave Craton in 2002, but like other articles that deal with Canadian kimberlite statistics, it provides no access to raw data.

Figure 15. Example of flood basalts in the Deccan Traps of Madhya Pradesh State, India. The Traps consist entirely of stratified lava flows with an estimated maximum depth of 3500 m and an estimated maximum surface area of 1,500,000 km^2. This basalt flood occurred in 66 Ma, almost exactly 1,200 Ma after the Mackenzie LIP, and concurrently with the Chicxulub asteroid impact in Mexico that coincided with the extinction of the dinosaurs (Keller 2008).

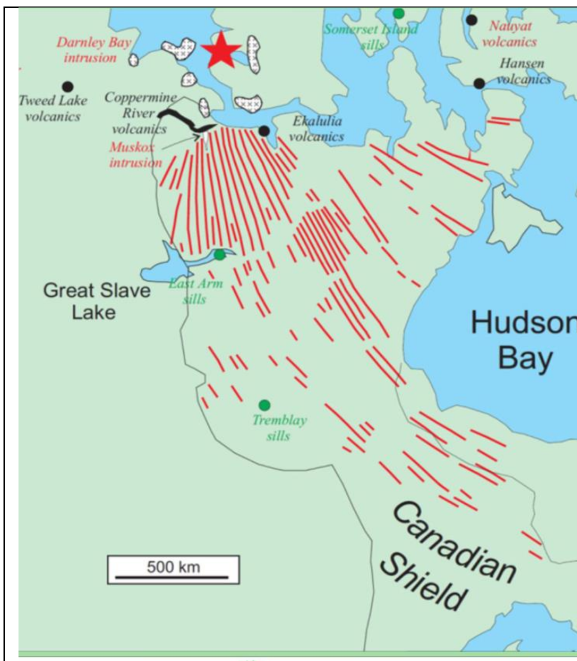


Figure 16. Mackenzie LIP giant dike swarm, 1267 Ma, radiating southward from the red star on Victoria Island that denotes a mantle plume as the proposed source of magmatism. Diagram and simplified caption from Day (2008), Buchan and Ernst (2004) and Hou (2012).

Figure 17. Franklin Dike, Baffin Island, Nunavut, Canada. I was unable to locate a comparable photo of the Mackenzie dike swarms. (Photo credit: Mike Beauregard 2012; Nunavut, Canada. Wikimedia Commons CC BY 2.0).

Given the extent to which projections have been made concerning links between kimberlite fields and the NEMP, my objective here is to extend those projections one final step to the edge of the Canadian Shield, probably by way of the MLIP. Perhaps even more importantly, this conjecture takes the NEMP to the edge of the North American plate where the continuity of the proposed track is terminated by plate movements reaching back toward the aggregation and disaggregation of Pangea.

Discussion.

I begin here by summarizing the three hypothetical causal chains that apparently produced three sets of mountains in one and the same place. First, the Appalachian orogeny more-or-less finished producing Mt. Washington and the Presidential Range at or near 200 Ma. Second, plate tectonics and disaggregating Pangea emplaced the White Mountains batholith and related Jurassic plutons near the base of Mt. Washington by 200-155 Ma. I suggest that these two events are not especially problematic. The third event, viz., the New England Mantle Plume track and its great environmental diversity, is much more problematic, hypothetically producing the third evolutionary sequence of considerable importance.

In Canada, the NEMP track conjecturally began at the MLIP at 1267 Ma on the north coast of the North American continent. Next it linked to one or more of a series of kimberlite fields at Slave Craton (613-55 Ma), Churchill (225-170 Ma), or Attawapiscat (180-134 Ma). Then came 12 Monteregian Hills with minimum ages of 118-122 Ma and maximum ages of 130-138 Ma, and 5 additional kimberlite-like intrusions with probable ages of 126±6 Ma.

In New Hampshire, the NEMP track probably had nothing to do with the intrusion of Jurassic plutons that formed at 186-192 Ma and 175 Ma, all in the older 200-155 Ma series. But during the period 130-100 Ma, concentrated at about 125 Ma, the NEMP emplaced a series of Cretaceous plutons in parallel with the earlier Jurassic plutons thereby producing ring dikes at Mt. Ossipee, Mt. Pawtuckaway and many other sites.

In the Atlantic Ocean, the NEMP track is surmounted by a great forest of seamounts emplaced on the ocean floor between 103 Ma and 80 Ma. Presumably the track then crossed the Mid-Atlantic Ridge at some unknown time, and the sequence ended at one of several possible destinations on the African plate including the Great Meteor guyot between 22 Ma and 11 Ma, the Seewarte Seamount chain, the Azores Triple Junction, the Cape Verde Islands or somewhere under the North African craton. The points on the track and the connective tissue that tie them together are equally important.

It would be useful to know more about relationships among the three mountains of different kinds that are present, all three struggling to occupy the same piece of New Hampshire real estate. Since these three distinctly different mountains sit almost on top of each other, it would be good to hear experts on each of them discuss interrelations among the whole cluster as a unit.

We need to know more about the numerous and diverse plutons, batholiths, caldera and related features surrounding the White Mountains within a radius of perhaps 160 km. Eusden's Team (2013) said, "These ring dikes are a key to understanding the emplacement of the WMMS central magmatic complexes." Expanding upon their brief allusion to the halo of neighboring ring-shaped morphological features – explaining just how they are keys to our understanding – would be most valuable.

It would be good to know more about the apparent uniqueness of the NEMP amidst the worldwide similarity of so many other mantle plumes. Koppers (2021a:382) and his six geologist colleagues, using a list[13] of 57 datasets of "volcanic regions postulated to be hotspots", rank ordered (Koppers et al 2021b) them regarding likelihood of satisfying all or most requirements for being genuine mantle plumes. NEMP is twenty-fifth on the list. Of those beginning 25, 23 were classified as 100%-oceanic, while 2 were 100%-continental. One continental pair is landlocked at Yellowstone, the other is at the Afar triangle, and both are radically different from the vast majority that may have never known any environment but the ocean floor.

Since NEMP's last activity appears to have occurred at the Great Meteor Guyot, Koppers' Team (2021b) classified it as an "oceanic" plume. However, since the NEMP apparently spent much of its early life under the Canadian Shield and a considerable period under the Appalachian Orogen, it almost certainly spent about a hundred million years as a "continental" plume before it began to produce seamounts in the Atlantic Ocean. I suggest that classifying it as 50%-continental rather than 100%-oceanic would be both reasonable and productive. And it would be good to know whether the NEMP is a genuine anomaly or a member of a poorly documented category of seamounts with similarly split personalities.

Apparently NEMP is the only mantle plume in Koppers' list that has such a split personality. Thus, it is neither surprising nor disappointing that Eusden's Team (2013:78) found the Hawaiian-Emperor seamounts to be poor role models for NEMP. That finding is exactly what we should predict. But as I have attempted to demonstrate, NEMP has a great deal to teach us because of the extraordinarily diversified crust that has passed over it while most of its cousins have spent their entire lives under the banal ocean floor. On a grand scale the crustal diversity may account for the generation of kimberlites and diamonds under the Canadian Shield, the intrusion of plutons into the St. Lawrence

[13] Koppers' Team (2021a,b) published their paper after Eusden's Team's (2013) book appeared, but the uniqueness of NEMP is not a recent discovery.

Platform and the Appalachian Orogen, and the extrusion of enormous seamounts and guyot in the Atlantic Ocean floor.

Throughout this article, I have dealt primarily with the diverse and ever-changing context within which the New England Mantle Plume may have operated and have paid little or no attention to the mantle plume itself. But consistently I have suspected that some of the questions raised here, explicitly or implicitly, might be attributable to peculiarities in the NEMP. As one possible example, my conjecture is that the plume's temperature or power was high at the MLIP but has been variable or cooler than average (Bao et al 2022, Perkins 2022) since then. Is that why it did not blast its way through the Canadian Shield but implanted plutons in the Appalachian Orogen, left the continental shelf essentially unmarked and extruded great seamounts on the Atlantic Ocean floor, while never producing a volcanic trail equivalent to the Hawaiian Islands?

Because of its complex history, NEMP invites research into potential relationships among mantle plumes, large igneous provinces such as the MLIP, and mass extinctions, all of which increasingly appear to work together as a global package. The multitude of environmental factors that generate climate change may contribute to global warming, and at the same time can contribute to disrupting the Gulf Stream (Boers 2021; Caesar 2021) thereby precipitously reopening the Ice Age with which Eusden's Team (2013) closed their book.

What accounts for the physical emergence of these three different mountains, and three different "kinds" of mountains, in the same place, spread over a period approaching 150 Ma? What is so special about that remarkable spot? Attributing its seemingly magical attractive powers to coincidence or God's will is not sufficient. In this regard, seeking interesting and important patterns in Tables 2 through 5 using a research methodology based on unsupervised pattern detection (Hand 2002) is likely to be more effective than using traditional hypothesis testing procedures.

After reading a great deal of geological material while preparing this article, and being emboldened by Alfred Wegener's persistence and success, I remain an anthropologist concerned largely with human implications of matters presented here. Virtually everything I have discussed in this article is a megascale structure, process or event including plate tectonics, orogenies, mantle plumes, batholiths and plutons, seamount fields, diatreme fields, Large Igneous Provinces, mass extinctions and planetary evolution. Having spent most of my life studying a population of 377 people living at a remote location in Central Australia (see author information below), writing this planet-scale article has been an enormously liberating experience.

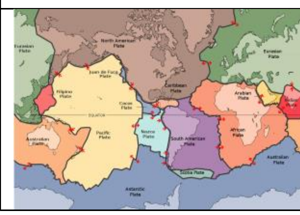
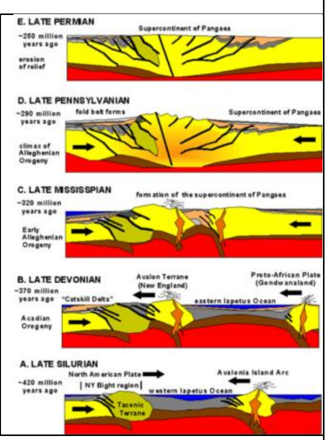
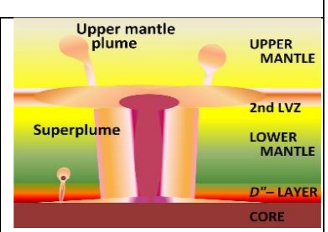
Appendices.

Appendix A. Online Dictionary and Glossary

Online Dictionary.

You can use your computer's online dictionary as a glossary that contains almost every word and expression in this article. On my computer, the dictionary window appears at the extreme lower-left corner of the screen with an invitation that says: "Type here to search" (it also accepts copied and pasted text).

Type or paste the search term, press <enter> to open the dictionary, and select from diverse text, image and map options. Return to your document when you finish using the dictionary. Your computer may operate somewhat differently, but it almost certainly provides this service.

Type here to search	Definitions – captions - sources	Images
Tectonic Plates	Simplified map of Earth's principal tectonic plates which were mapped in the second half of the 20th century. Red arrows indicate direction of movement at plate boundaries. Text source: US Geological Survey, 1 February 1996. Plate tectonics. Public Domain. https://en.wikipedia.org/wiki/Plate_tectonics. Image source: Wikipedia 28 January 2022. Earth's principal tectonic plates. https://en.wikipedia.org/wiki/Plate_tectonics#/media/File:Plates_tect2_en.svg	
Appala-chian orogeny	Sometimes an entire ocean closes as tectonic plates converge, and a collisional mountain range forms as the crust is compressed, crumpled, and thickened. The Appalachian Mountains formed during such a collision of continents 500 to 300 million years ago. In their prime they probably had peaks as high as those in the Himalayas, but over the past 300 million years, they have eroded to more modest heights. Text source: US National Park Service, 11 February 2020. Convergent Plate Boundaries—Collisional Mountain Ranges. Public Domain. https://www.nps.gov/subjects/geology/plate-tectonics-collisional-mountain-ranges.htm Image source: US Geological Survey 2006. Alleghanian orogeny.svg. Public Domain. https://en.wikipedia.org/wiki/Alleghanian_orogeny#/media/File:Appalachian_orogeny.jpg	
Mantle plume	A mantle plume is a proposed mechanism of convection within the Earth's mantle. Because the plume head partially melts on reaching shallow depths, a plume is often invoked as the cause of volcanic hotspots, such as Hawaii or Iceland, and large igneous provinces such as the Deccan and Siberian Traps. Text source: Wikipedia 2022. Mantle Plume. https://en.wikipedia.org/wiki/Mantle_plume Image source: Brews Ohare, 2010. Lower Mantle Superplume.PNG. CC-BY-SA-3.0 https://commons.wikimedia.org/wiki/File:Lower_Mantle_Superplume.PNG	

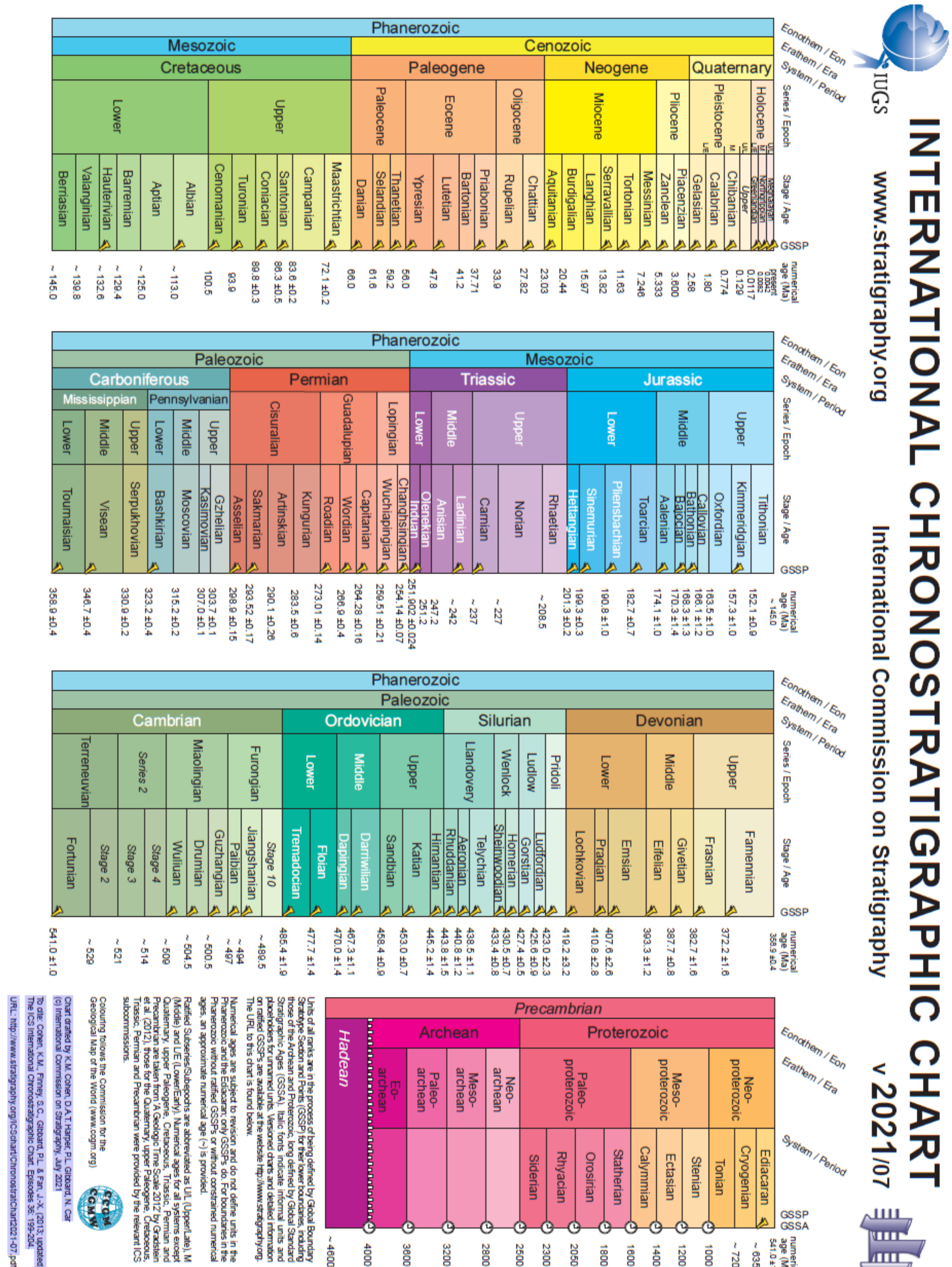
Glossary of acronyms and abbreviations

My online dictionary is not good at finding acronyms and abbreviations, so I prepared the following glossary that contains all acronyms and abbreviations that appear in this article.

Term	Definition
Technical terms	
CAMP	Central Atlantic Magmatic Province
FAO	Food and Agriculture Organization of the United Nations
ICS	International Commission on Stratigraphy
HALIP	High Arctic Large Igneous Province
KF	Kimberlite fields
m, km	Meters, kilometers
LIDAR	Light Detection and Ranging technology
LIP	Large Igneous Province
LIP-Com	Large Igneous Provinces Commission
MHIP	Monteregian Hills Igneous Province
NASA	National Aeronautics and Space Administration
NEMP	New England Mantle Plume
NEHT	New England Hotspot Track
NEQMP	New England – Quebec Magmatic Province
NES	New England Seamounts
NOAA	National Oceanographic and Atmospheric Administration
SPD	Supervised Pattern Detection
UPD	Unsupervised Pattern Detection
WMMS	White Mountains Magma Series
WMPVS	White Mountains Plutonic-Volcanic Suite
Geochronologic Dating by North American Commission on Stratigraphic Nomenclature, 2005. Dates bearing these abbreviations are approximate.	
Ka	Kilo-annum, 10^3 years, thousands
Ma	Mega-annum,10^6 years, millions of years
Ga	Giga-annum, 10^9 years, billions of years
State Name Codes by United States Postal Service	
MA	Massachusetts
ME	Maine
NH	New Hampshire
NY	New York
VT	Vermont
International Province Codes by Canada Post	
NT	Northwest Territories
NU	Nunavut
ON	Ontario
QC	Quebec

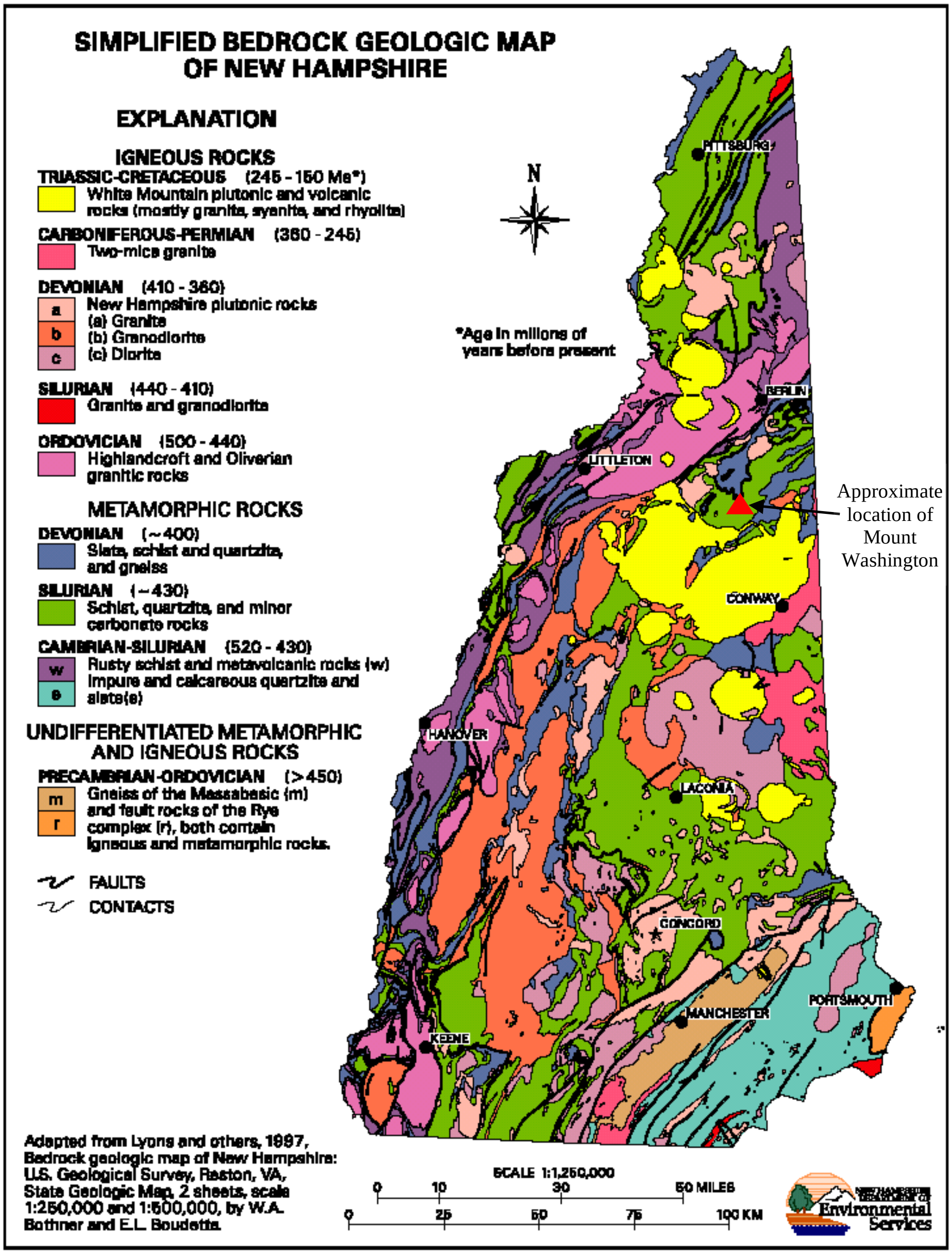
Appendix B. International Chronostratigraphic Chart

International Commission on Stratigraphy 2021 (ICS-21)



Appendix C. Simplified bedrock geologic map of New Hampshire, USGS 1997.

This is not the newest version, but it is acceptable for my purposes. The key distinguishes between igneous and metamorphic rocks, and within those categories chronostratigraphic periods are at a useable scale and are labeled generically (disregard alphabetic codes). Unfortunately, this map does not distinguish between 200-155 Ma and 130-100 Ma intrusions, but Figure 5 does make that distinction very clearly. A red triangle indicates the approximate location of Mt. Washington wherever it appears on a Figure (USGS 1997).

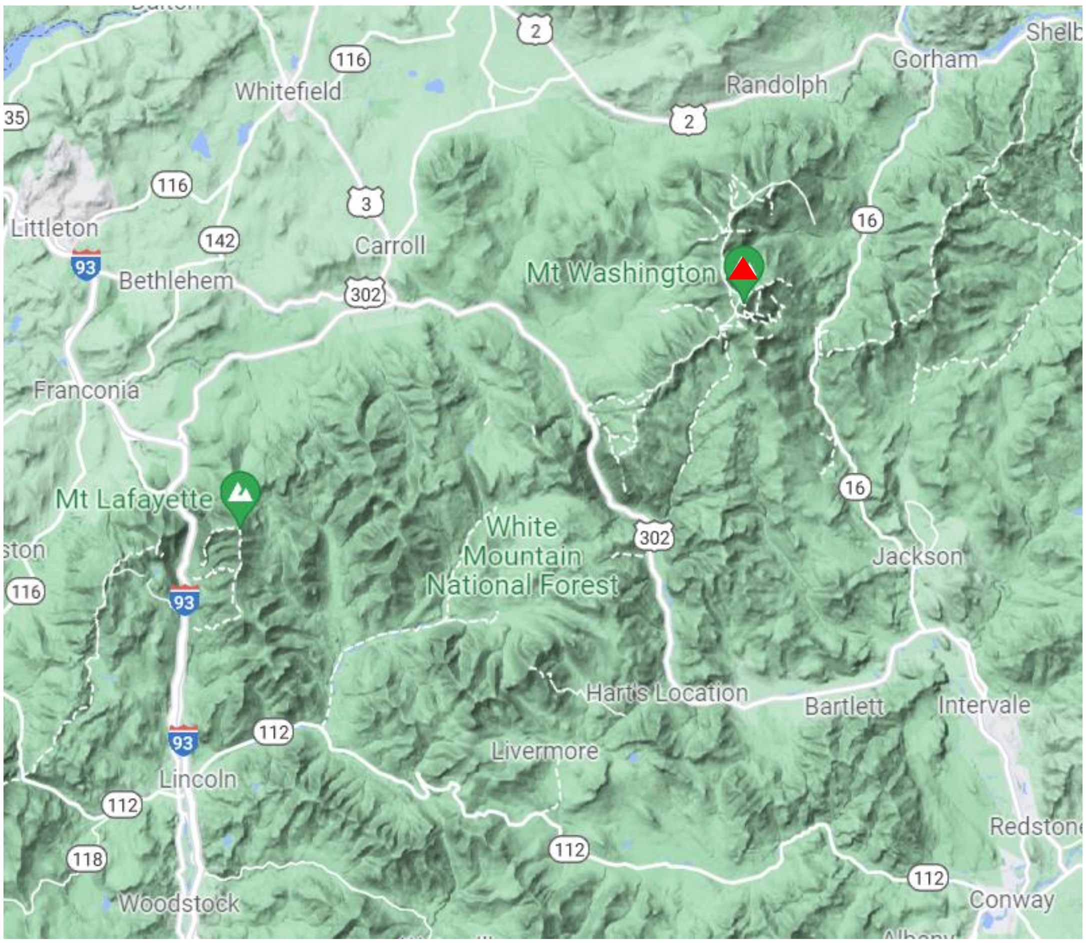


Appendix D. Highway map of the White Mountains of New Hampshire.

This LIDAR-based terrain map with named locations provides support for all Figures (Google Maps 2021).

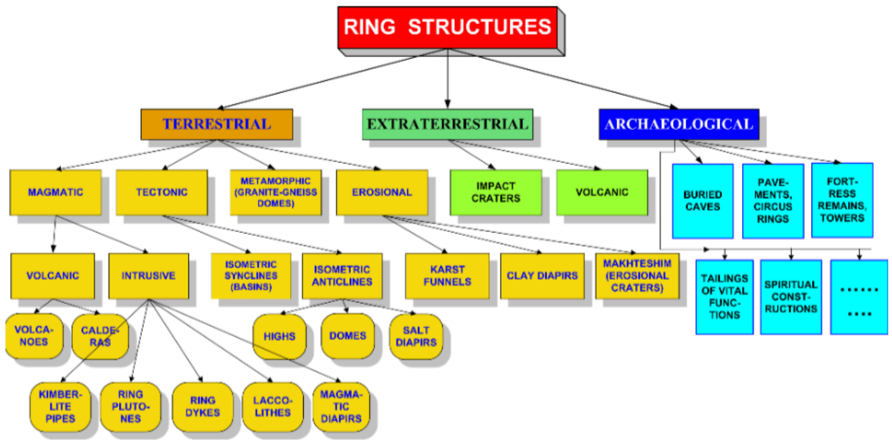
The shape and coverage of this map approximate those of the six unnumbered and unlabeled topographic maps that appear on Eusden's Team (2013:56, 59, 62, 73, 83 and 90).

Franconia Notch (I-93), Crawford Notch (US-302) and Pinkham Notch (NH-16) define implicit White Mountain quadrants - NW (null), NE, SE and SW – discussed in Figures 1 and 2.



Appendix E. Classification of ring structures.

Occurrences in the Earth's environments (Eppelbaum 2008).



References.

When links do not work, search by author and title.

Adams, Frank D. 1903. The Monteregian Hills: A Canadian Petrographical Province. *The Journal of Geology* 11(3):239-282. https://www.jstor.org/stable/30055562.

Albritton, Claude 1975. *Philosophy of Geohistory 1785-1970. Benchmark Papers in Geology.* Stroudsburg, PA: Dowden, Hutchinson and Ross.

Allen, T., Creasy, J., Davis, P.T., Eusden, J.D., Fowler, B., and Thompson, W.B., 2001, The Notches: Bedrock and Surficial Geology of New Hampshire's White Mountains, in Richard Bailey and David West, eds, *Guidebook of Field Trips for the Geological Society of America's 2001 Annual Meeting, Boston.* Geological Society of America, Boulder, Colorado, pp. C1-C33. http://tim.thorpeallen.net/Research/Papers/Notches.pdf

Bao, Xiyuan, Carolina R. Lithgow-Bertelloni, Matthew G. Jackson, Barbara Romanowicz 2022. On the relative temperatures of Earth's volcanic hotspots and mid-ocean ridges. *Science*, 6 Jan 2022, Vol 375, Issue 6576, pp. 57-61; DOI:10.1126/science.abj8944.

Beauregard, Mike, 2012. Franklin Dike, Baffin Island, Nunavut, Canada (photo). By Mike Beauregard from Nunavut, Canada - Franklin dike, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=47455448.

Boers, Niklas 2021. Observation-based early-warning signals for a collapse of the Atlantic Meridional Overturning Circulation. *Nature Climate Change* 11, 680–688. https://doi.org/10.1038/s41558-021-01097-4.

Britannica, The Editors of Encyclopaedia. "James Ussher". *Encyclopedia Britannica*, 17 Mar. 2021, https://www.britannica.com/biography/James-Ussher. Accessed 5 December 2021.

Buchan, K.L. & Ernst, R.E. (2004). Diabase dike swarms and related units in Canada and adjacent regions. *Geological Survey of Canada Map 2022A*, with map 1:5,000,000 and accompanying notes.

Buchan, Kenneth L. and Richard E. Ernst 2006. The High Arctic Large Igneous Province (HALIP): Evidence for an Associated Giant Radiating Dyke Swarm. *Large Igneous Provinces Commission,* April 2006 LIP of the Month. http://www.largeigneousprovinces.org/06apr

Caesar, L., McCarthy, G.D., Thornalley, D.J.R. et al. 2021. Current Atlantic Meridional Overturning Circulation weakest in last millennium. *Nature Geoscience* 14, 118–120 (2021). https://doi.org/10.1038/s41561-021-00699-z

Canada Physio Regions Map 2006. Natural Resources Canada. *The Atlas of Canada 1906-2006.* http://www.canada-maps.net/maps/canada-physio-regions-map.htm

OR http://www.map-of-the-world.info/mapserver/canada-maps/physio-regions.jpg

Chamov, N.P., Stukalova, I.E., Sokolov, S.Y. et al. 2019. Tectonic-Sedimentary System of the Atlantis–Meteor Seamounts (North Atlantic): Volcanism and Sedimentation in the Late Miocene–Pliocene and Position in the Atlantic–Arctic Rift System. *Lithol Miner Resour* 54, 374–389 (2019). https://doi.org/10.1134/S0024490219050043 .

Darwin, Charles 1859. *On the origin of species by means of natural selection.* London: John Murray. http://darwin-online.org.uk/content/frameset?itemID=F373&viewtype=text&pageseq=1

Day, James M.D. 2008. The 1.27 Ga Mackenzie Large Igneous Province and Muskox layered intrusion. September 2008 LIP of the Month. *Large Igneous Provinces Commission* http://www.largeigneousprovinces.org/08sep .

Duncan, R.A. 1984. Age progressive volcanism in the New England Seamounts and the opening of the central Atlantic Ocean. *Journal of Geophysical Research: Solid Earth,* Vol 89, Issue B12, 10 Nov 1984 pp. 9980-9990. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/JB089iB12p09980 https://doi.org/10.1029/JB089iB12p09980 .

Eby, G.N. 1984. Geochronology of the Monteregian Hills alkaline igneous province, Quebec. *Geology*, 12, pp. 468–470. https://doi.org/10.1130/0091-7613(1984)12<468:GOTMHA>2.0.CO;2

Eby, G.N. 1995. Part 1: White Mountain magma series. Third Hutton Symposium on Granites and Related Rocks – Pre-Conference Field Trip Guide, August 22–24, 1995, Lowell, MA, 23 p. https://www.researchgate.net/publication/256496442_White_Mountain_Magma_Series

Einstein, Albert, 1950. "Everything should be made as simple as possible, but no simpler." Quoted by Roger Sessions, *New York Times*, 8 January 1950. https://en.wikiquote.org/wiki/Albert_Einstein

Eldredge, Niles and S. J. Gould (1972). Punctuated equilibria: an alternative to phyletic gradualism. In T.J.M. Schopf, ed., *Models in Paleobiology*. San Francisco: Freeman Cooper. pp. 82-115. http://www.blackwellpublishing.com/ridley/classictexts/eldredge.pdf

Eppelbaum, Lev V., Michael Ezersky, Abdallah S. Al-Zoubi, V. I. Goldshmidt, Anatoly Legchenko 2008. Study of the factors affecting the karst volume assessment in the Dead Sea sinkhole problem using microgravity field analysis and 3-D modeling. *Advances in Geosciences* 19:97-115, May 2008. DOI: 10.5194/adgeo-19-97-2008.

Ernst, Richard E. 2014. Magmatic pathways in Large Igneous Provinces: Initial thoughts on a research framework. *December 2014 LIP of the Month.* Large Igneous Provinces Commission. http://www.largeigneousprovinces.org/14dec .

Eusden, John Dykstra, Woodrow B. Thompson, Brian K. Fowler, P. Thom Davis, W. A. Bothner, Richard Boisvert, John W. Creasy, 2013 (aka Eusden's Team). *The geology of New Hampshire's White Mountains.* Lyme, NH: Durand Press.

FAO 2021. Corner Rise Seamounts. *Food and Agriculture Organization of the United Nations (FAO). Northwest Atlantic Fisheries Organization (NAFO).* http://www.fao.org/fishery/vme/23614/en

Foster J. and D. T. A. Symons 1979. Defining a paleomagnetic polarity pattern in the Monteregian intrusives. *Canadian Journal of Earth Sciences* 16(9). https://doi.org/10.1139/e79-159

Foulger, Gillian R. 2010. *Plates vs Plumes: A Geological Controversy. Geology Today,* Vol. 28, No. 1. Wiley-Blackwell: The Geological Society of London, 2021. www.MantlePlumes.org

Google Earth, 2021. New England and Corner Rise Seamounts. https://earth.google.com/web/search/Boston,+MA/@38.39228433,-51.17656876,137.38598999a,2611356.11260682d,35y,-0h,0t,0r/data=CigiJgokCbsk1akS7CBAEdXDHGhE6wLAGUCiot6YnkbAIWxP9_mEa0vA

Google Maps, 2021. Highway map of the White Mountains of New Hampshire. https://www.google.com/maps/place/Mt+Washington/

Greshko, Michael 2019. What are mass extinctions, and what causes them*? National Geographic Magazine*, 26 September 2019. https://www.nationalgeographic.com/science/article/mass-extinction

Hand, David J. 2002. Pattern detection and discovery. In David J. Hand, Niall M. Adams, Richard J. Bolton, eds. Pattern Detection and Discovery. Lecture Notes in Artificial Intelligence 2447:1-12. ESF Exploratory Workshop, Proceedings. London, UK, September 16- 19, 2002. https://link.springer.com/chapter/10.1007/3-540-45728-3_1

Heaman, Larry M. and Bruce A. Kjarsgaard 2003. The temporal evolution of North American kimberlites. *International Kimberlite Conference: Long Abstract, Vol. 8:1-5*. Victoria BC. 22 June 2003. DOI: https://doi.org/10.29173/ikc3048.

Heaman, Larry M., David Phillips, Graham Pearson, 2019. Dating kimberlites: methods and emplacement patterns through time. *Elements* (2019) 15 (6): 399–404. https://doi.org/10.2138/gselements.15.6.399

Hibbard, J.P., van Staal, C.R., Rankin, D.W. and Williams, H. 2006. *Tectonic Lithofacies Map of the Appalachian Orogen.* Canada-United States of America; Geological Survey of Canada, Map2096a, Sheet 2 of 2, North Sheet, scale 1:1,500,000. https://i0.wp.com/caboxgeopark.org/wp-content/uploads/2019/01/Tectonic-Lithofacies-Map-5s.jpg

Hou, Guiting 2012. Mechanism for three types of mafic dike swarms. *Geoscience Frontiers* 3(2): 217-223. doi: 10.1016/j.gsf.2011.10.003

Hutton, James 1785/1987. *The 1785 abstract of James Hutton's Theory of the Earth.* University of Edinburgh. Department of Geology: Scottish Academic Press.

ICS-21 International Commission on Stratigraphy, 21 November 2021. International Chronostratigraphic Chart. https://stratigraphy.org/chart

Keller, Gerta 2008. Image of Deccan Traps in Madhya Pradesh State, India. By G. Keller, Professor of Geosciences, Princeton University. https://www.wired.com/images_blogs/photos/uncategorized/2008/12/15/deccantraps.jpg).

Kjarsgaard, B.A., and Levinson, A.A., 2002. Diamonds in Canada. *Gems and Gemology* 38, 208-239. https://www.gia.edu/doc/Fall-2002-Gems-Gemology-Diamonds-in-Canada.pdf .

Koppers, A.A.P., Becker, T.W., Jackson, M.G. *et al.* 2021a. Mantle plumes and their role in Earth processes. *Nat Rev Earth Environ* **2,** 382–401. http://www-udc.ig.utexas.edu/external/becker/preprints/k21.pdf https://doi.org/10.1038/s43017-021-00168-6 .

Koppers, A.A.P., Becker, T.W., Jackson, M.G. *et al.* 2021b. Supplementary Information: Deep mantle plume scores. Ranking of 57 mantle plumes. https://static-content.springer.com/esm/art%3A10.1038%2Fs43017-021-00168-6/MediaObjects/43017_2021_168_MOESM1_ESM.pdf

LIP-Com 2021 (Large Igneous Provinces Commission 2021). What are Large Igneous Provinces? http://www.largeigneousprovinces.org/

Lovejoy, Arthur O. (1936). *The Great Chain of Being: A Study of the History of an Idea*. Harper.

Luis, J. Freire, J.M. Miranda, A. Galdeano, P. Patriat, J.C. Rossignol, L.A. Mendes Victor 1994. The Azores triple junction evolution since 10 Ma from an aeromagnetic survey of the Mid-Atlantic Ridge**.** *Earth and Planetary Science Letters***,** Volume 125, Issues 1–4 July 1994, Pages 439-459**.** https://www.sciencedirect.com/science/article/abs/pii/0012821X94902313?via%3Dihub

Lyell, Charles 1830-33. Principles of Geology. London: John Murray.Marine Gazetteer Placedetails 20Feb2017. https://www.marineregions.org/gazetteer.php?p=details&id=4565

Marple, Ronald T., James D. Hurd, and Robert J. Altamura 2018 (aka Marple's Team). Ring-shaped morphological features and interpreted small seamounts between southern Quebec (Canada) and the New England seamounts (USA) and their possible association with the New England hotspot track. *Atlantic Geoscience* 54, 223–265. doi:10.4138/atlgeol.2018.008.

McGregor, Bonnie A. and Krause, Dale C. 1972. Evolution of the sea floor in the Corner Seamounts Area. Harvard University Astrophysics Data System. *Journal of*

Geophysical Research, 77:14 2526-2534. https://ui.adsabs.harvard.edu/abs/1972JGR....77.2526M/abstract .

McHone, J.G. and S.N. Shake 1992. Structural control of Mesozoic magmatism in New England. In R. Mason (ed.), *Basement Tectonics* 7:399-407. The Netherlands: Kluwer Academic Publishers.

McHone, J. Gregory (undated: 2003 or later). CAMP: Igneous Features and Geodynamic Models of Rifting and Magmatism Around the Central Atlantic Ocean, pp. 1-11. http://www.mantleplumes.org/CAMP.html

Merriam-Webster. (n.d.). Occam's razor. In *Merriam-Webster.com dictionary*. https://www.merriam-webster.com/dictionary/Occam%27s%20razor . Retrieved December 5, 2021.

Mitchell, R. H. 1979. The alleged kimberlite-carbonatite relationship: additional contrary mineralogical evidence. *American Journal of Science*, 279, pp. 570-589. *(7) (PDF) The Ile Bizard intrusion, Montreal, Quebec—kimberlite or lamprophyre?: Reply*. Available from: https://www.researchgate.net/publication/237172568_The_Ile_Bizard_intrusion_Montreal_Quebec-kimberlite_or_lamprophyre_Reply [accessed Oct 29 2021].

Mohn, Christian 2010. Great Meteor Seamount. *Oceanography* 23(1):106-107. https://tos.org/oceanography/assets/docs/23-1_mohn.pdf

Morgan, W. 1971. Convection Plumes in the Lower Mantle. *Nature* **230,** 42–43. https://doi.org/10.1038/230042a0

NASA/METI/AIST/Japan Space Systems, and U.S./Japan ASTER Science Team, 23 September 2016. https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA21536, Public Domain, https://commons.wikimedia.org/w/index.php?curid=66944858

NOAA 2022. Ocean Explorer Site Map. https://oceanexplorer.noaa.gov/sitemap.html

NOAA/Watling, Les 2003. Geological origin of the New England Seamount Chain. NOAA Ocean Explorer. http://oceanexplorer.noaa.gov/explorations/03mountains/background/geology/geology.html

NOAA 2013. Seewarte Seamounts. Public domain. https://en.wikipedia.org/wiki/Seewarte_Seamounts#/media/File:Seewarte3d.svg

Perkins, Sid, 6Jan2022. Some volcanic hot spots may have a surprisingly shallow heat source. *Science News* https://www.sciencenews.org/article/volcano-hot-spots-shallow-heat-source-tectonic-plates-mantle .

Popper, Karl 1963. *Conjectures and Refutations.* London: Routledge.

Raeside, Robert P. and Herwart Helmstae 1982. The Ile Bizard intrusion, Montreal, Quebec-kimberlite or lamprophyre? *Canadian. Journal of Earth Science* 19, 1996-2011. https://www.researchgate.net/publication/237172405_The_Ile_Bizard_intrusion_Montreal_Quebec-kimberlite_or_lamprophyre.

Raeside, Robert P. and Herwart Helmstae 1983. The Ile Bizard intrusion, Montreal, Quebec-kimberlite or lamprophyre?: Reply. *Canadian. Journal of Earth Science* 20. 1496-1498. https://www.researchgate.net/publication/237172568_The_Ile_Bizard_intrusion_Montreal_Quebec-kimberlite_or_lamprophyre_Reply.

Ramberg, I.B., Bryhni, I., Nottvedt, A. and Rangnes (eds.) 2008. *The Making of a Land: Geology of Norway.* Trondheimn: Norsk Geologisk Forening. https://www.google.com/books/edition/The_Making_of_a_Land/rMVNE0F2SckC?hl=en&gbpv=1

Raup, D. & Sepkoski, J. (1982). "Mass extinctions in the marine fossil record". *Science* 215: 1501–1503. DOI:10.1126/science.215.4539.1501.

Rollinson, Hugh 2012. Review of G.R. Foulger 2010. *Plates vs Plumes: A Geological Controversy. Geology Today*, 28(1):39-40. http://www.mantleplumes.org/WebDocuments/P%5E2Rev_HughRollinson.pdf.

Ryder, Richard 1970. Speciesism Again: the original leaflet. *Critical Society*, Issue 2, Spring 2010. Archived 14 November 2012 at the Wayback Machine. http://www.criticalsocietyjournal.org.uk/Archives_files/1.%20Speciesism%20Again.pdf

Scott Smith, Barbara H. 2008. Canadian kimberlites: Geological characteristics relevant to emplacement. *Journal of Volcanology and Geothermal Research* 174(1–3)9-19. https://www.semanticscholar.org/paper/Canadian-kimberlites%3A-Geological-characteristics-to-Smith/16ea82fb019191cfb8d09873ec97366a089d9bd0/figure/0

Shank, Timothy M. March 2010 and 2 Oct 2015. SPOTLIGHT 4: New England and Corner Rise Seamounts. *Oceanography* Vol.23(1):104-5. https://tos.org/oceanography/assets/docs/23-1_shank2.pdf

Singer, Peter 1975. *Animal Liberation: A New Ethics for our Treatment of Animals*. New York: Random House.

Smith, William 1815/2014. *A Geological Map of England and Wales and Part of Scotland.* Reproduced by the British Geological Survey from an original held in its archives. https://www.geolsoc.org.uk/bws1815 .

Sowers, D., J.A.Dijkstra, K.Mello, G.Masetti, M.Malik, L.AlanMayer 2020. Chapter 56 - Application of the coastal and marine ecological classification standard to Gosnold Seamount, North Atlantic Ocean, pp. 903-916. https://doi.org/10.1016/B978-0-12-814960-7.00056-7 . In Peter T. Harris and Elaine Baker, eds. 2020. *Seafloor Geomorphology as Benthic Habitat, 2nd ed.: GeoHab Atlas of Seafloor Geomorphic Features and Benthic Habitats.* Elsevier ScienceDirect. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/guyot.

Tharp, Marie, Bruce Heezen and Heinrich Berann 1977. *The World Ocean Floor Map.* National Geographic; Columbia University; Lamont-Doherty Geological Observatory; The Earth Institute. https://www.nationalgeographic.com/culture/article/marie-tharp-map-ocean-floor

Tollo, Richard P., Louise Corriveau, James McLelland, Mervin J. Bartholomew 2004. Proterozoic tectonic evolution of the Grenville orogen in North America: An introduction. In Tollo, Richard P., Corriveau, Louise, McLelland, James, et al. (eds.). *Proterozoic tectonic evolution of the Grenville orogen in North America. Geological Society of America Memoir. 197*. Boulder, CO. pp. 1–18. https://pubs.geoscienceworld.org/gsa/books/book/208/chapter/3794127/Proterozoic-tectonic-evolution-of-the-Grenville

Wilson, J. Tuzo 1963. A possible origin of the Hawaiian Islands. *Canadian Journal of Physics* 41(6):863-870. https://cdnsciencepub.com/doi/abs/10.1139/p63-094

USA.FisherMap.org. Atlantic Ocean depth map / nautical chart https://usa.fishermap.org/depth-map/atlantic-ocean/

USGS 1997. *Simplified bedrock geologic map of New Hampshire.* US Geological Survey, Reston, VA. https://www.nhgeology.org/sim_br.pdf

Verhoef, Jacob 1984. A geophysical study of the Atlantis-Meteor seamount complex. *Geologica Ultraiectina* 38:1-153. Utrecht University Repository: Doctoral dissertation. http://dspace.library.uu.nl/handle/1874/238521

Voltaire 1764/1769/1979. *Philosophical dictionary,* 5th ed. Quoted in *Oxford Dictionary of Quotations,* 3rd ed., p. 561.

Wegener, Alfred 1912/1929/1966. *The Origin of Continents and Oceans*, 4th ed. Translated from the German by John Biram. New York: Dover Publications.

Wikipedia 2022a. White Mountains (New Hampshire). https://en.wikipedia.org/wiki/White_Mountains_(New_Hampshire)

Wikipedia 2022b. List of extinction events. https://en.wikipedia.org/wiki/List_of_extinction_events

Winchester, Simon 2003. *Krakatoa: The Day the World Exploded August 27, 1888*. New York: HarperCollins.

Winchester, Simon 2001. *The Map that Changed the World: William Smith and the Birth of Modern Geology*. New York: HarperCollins.

Zurevinski, S. E., L. M. Heaman, R. A. Creaser, and P. Strand 2008. The Churchill kimberlite field, Nunavut, Canada: petrography, mineral chemistry, and geochronology. *Canadian Journal of Earth Sciences*. 30 October 2008. https://doi.org/10.1139/E08-052

Zurevinski, S.E., L. M. Heaman, Robert A. Creaser 2011. The origin of Triassic/Jurassic kimberlite magmatism, Canada: Two mantle sources revealed from the Sr-Nd isotopic composition of groundmass perovskite. *Geochemistry Geophysics Geosystems* 12(9) DOI: 10.1029/2011GC003659.

Author Information.

I am an 81-year-old retired cultural anthropologist with no current academic affiliation. My 50 years of anthropological research focused primarily on descent, marriage, kinship and age among the Alyawarra speaking indigenous people of Central Australia whose biological and cultural roots reach back locally about 60,000 years.

As of today, my online materials available at ResearchGate (RG) include 145 articles, preprints, numerical data files and field collections of ethnographic photographs and music. My average readership rate at RG stands at 344 reads per month, a total of 9276 reads in the 27 months since I established my account on 1 January 2020. My RG Research Interest score is higher than 75% of all RG members, and higher than 89% of RG researchers in cultural anthropology. Representative publications listed below are in diverse fields including social science research methods; Australian Aboriginal kinship; history and social organization of nonhuman primates; and evolution and sociobiology of ants.

Education.

University of Mississippi, 1967. B.A. Degree in Philosophy, Psychology, Anthropology
University of Sydney, Australia 1970. Visiting Post-graduate Student in Australian Aboriginal Studies
University of Washington, Seattle, 1973. Ph.D. Degree in Cultural Anthropology
University of California, Berkeley, 1976. National Institute of Mental Health Post-Doctoral Trainee in Quantitative Public Policy Anthropology

Representative publications.

Denham, Woodrow W. 1973. The detection of patterns in Alyawarra nonverbal behavior. Seattle: University of Washington, doctoral dissertation. https://www.researchgate.net/publication/247830886_The_Detection_of_Patterns_in_Alyawara_Nonverbal_Behaviour

Denham, Woodrow W. 1979. Research Design and Research Proposal Checklists. *Anthropology Newsletter* 20(4):9-11; April 1979. https://www.researchgate.net/publication/240657169_Research_design_and_research_proposal_checklists

Denham, Woodrow W., Chad McDaniel and John R. Atkins 1979. Aranda and Alyawara kinship: a quantitative argument for a double helix model. *American Ethnologist* 6(1):1-24. https://anthrosource.onlinelibrary.wiley.com/doi/abs/10.1525/ae.1979.6.1.02a00010.

Denham, Woodrow W. and Douglas R. White 2005. Multiple Measures of Alyawarra Kinship. *Field Methods* 17(1):70-101. https://escholarship.org/uc/item/9xs4j0kg

Denham, Woodrow W. 2012. Kinship, Marriage and Age in Aboriginal Australia. *Mathematical Anthropology and Cultural Theory* 4(1):1-79. http://mathematicalanthropology.org/Pdf/MACT_Denham_0512.pdf

Denham, Woodrow W. 2013. Beyond Fictions of Closure in Australian Aboriginal Kinship. *Mathematical Anthropology and Cultural Theory* 5(1):1-90. http://mathematicalanthropology.org/Pdf/Denham_MACT0513.pdf

Denham, Woodrow W. 2018. Aboriginal Men Coming of Age in Central Australia. *Mathematical Anthropology and Cultural Theory* 13(1):1-142. http://mathematicalanthropology.org/Pdf/DenhamMACT1118.pdf

Denham, Woodrow W. 1971. Energy Relations and Some Basic Properties of Primate Social Organization. *American Anthropologist* 73(1):77 – 95. DOI: 10.1525/aa.1971.73.1.02a00060.

Denham, Woodrow W. 1987. *West Indian Green Monkeys: Problems in Historical Biogeography.* Basel, Switzerland: S. Karger AG. https://www.researchgate.net/publication/340091901_West_Indian_Green_Monkeys_Problems_in_Historical_Biogeography

Denham, Woodrow W. 2019. Sociality in E. O. Wilson's *Genesis*: Expanding the Past, Imagining the Future. *Mathematical Anthropology and Cultural Theory* 14(1):1-37. http://mathematicalanthropology.org/Pdf/DenhamMACT1019.pdf