Using Google Earth to Teach the Magnitude of Deep Time

By Joel D. Parker

Most timeline analogies of geologic and evolutionary time are fundamentally flawed. They trade off the problem of grasping very long times for the problem of grasping very short distances. The result is an understanding of relative time with little comprehension of absolute time. Earlier work has shown that the distances most easily understood by teachers and students are those most people can experience directly. Thus most timeline analogies are flawed by either overcompressing an experienceable time or relying on an unexperienceable distance. Under the constraint of experienceability, the best timeline to distance scale must be at least 75 miles and no more than about 500 miles long. Using Google Earth, one can construct such ideal timeline analogies relative to a point in the classroom with locally adaptable markers for important events in geologic time. I have used these analogies for several years in university and public lectures to great effect.

Teaching deep time (the time scale of evolutionary, geologic, and cosmological events) is one of the great classroom challenges because the lengths of time involved are outside of human experience (Tretter et al. 2006; Hillis 2007; Catley and Novick 2009; Jones and Taylor 2009). However, this extreme magnitude is one of the key learning objectives when teaching biological evolution because it is essential for Darwin's theory to work. Indeed, one of the main arguments used against evolution is that the Earth is not as old as science says it is, and this remains one of the primary misconceptions for not accepting Darwin's theory (Cotner, Brooks, and Moore 2010). Traditionally, the problem with deep time has been divided into two parts: teaching the relative order of events (relative time) and the comprehension of the magnitude of deep time (absolute time). Most timeline analogies work very well for relative time, but finding appropriate analogies for absolute time remains a great problem (Hillis 2007; Cotner, Brooks, and Moore 2010). Here, I describe a locally adaptable analogy that works to teach both relative and absolute time. The analogy consists of a local and culturally specific timeline bounded at the both extremes by distances that can be physically experienced. Such custom timelines are easily made with Google Earth (a free program downloadable from *http://earth.google.com/*). I have used this analogy in both first-year undergraduate lectures and in public talks to mature audiences, receiving excellent feedback in all cases.

The key difficulty with perceiving the magnitude of time is that a student cannot meaningfully relate an experienced length of time to any of the commonly used timeline analogies (clock face, calendar year, interior building distances, toilet paper roll, playing fields, human body, etc.). In these spatial analogies, the length of a student's life, and sometimes all of human written history, maps onto a microscopic distance that cannot be directly experienced. When the analogous distances become microscopic, the perception problem is only shifted from the very big to the very small. Perception at both ends of the spectrum is difficult, and students tend to lump events and sizes at either end into a very big and a very small category, losing the differentiations within these extreme categories (Tretter et al. 2006). Indeed, precipitous drops in the accuracy of scale perception have been observed for scales below the visible (micrometers) and those beyond a million meters (about 600 mi.; Tretter et al. 2006; Jones et al. 2008). These results suggest that the widest distance scale that at least half of teachers and students can be expected to easily comprehend will extend from just under a millimeter to hundreds of kilometers.

If we construct a timeline analogy under the above constraints of human experience on both the recent and distant ends of our timeline, then an appropriate range of distance can be determined. The smallest distance that a student might be able to apprehend by visualization without a microscope is about 0.5 mm (1/50th of an inch). The maximum range an average student might experience in the industrialized world is a drivable distance, which is the suggested reason for the 600 mi. (about 1,000 km) limit (Tretter et al. 2006). On the time side, if we consider the longest length of time experienced by a student as his or her lifetime (about 18 years), then for a college freshman we set 0.5 mm = 18 years. This gives a scale of around 59 million years per mile or about 37 million years per kilometer. On this scale, the origin of the Earth (4.6 billion years ago) maps to about 75 mi. (121 km) away, well within our maximum limit. The analogy is then constructed from a specific point in the lecture hall (a taped line) to some local landmark at least 75 mi. away but less than a day's journey by car or train.

The freely available program Google Earth is ideally designed for creating these properly scaled local analogies. The program already has a track record of being used for many educational purposes (*http://earth.google.co.uk/outreach/edu_culture.html*). The program can be used to plot routes between chosen points and to calculate distances between specific points in different distance units. One can map any landmark that is the correct distance from a specific lecture/presentation location and create a locally ideal distance analogy. Thus, Google Earth makes it practical to set up a rationally designed custom analogy from almost any major university lecture hall in the world.

Methods and example

Preparation

Some initial time must be invested in customizing the exercise to go from the chosen landmark all the way to the interior of the building where the presentation is being given. In order to relate this to students' real experience, the instructor needs to select a landmark more than 75 mi. away

FIGURE 1

Step-by-step tips for using Google Earth to plot the analogy route.

1. To start, open Google Earth and go to your presentation location, zoom in to the highest magnification and place a marker on the building, then zoom out and place a marker on your chosen landmark.
    - To get the initial route and distance right, click on your presentation location marker, select "Directions to here," then enter the location of your landmark under the "Directions from" tab on the left. Click on the magnifying glass on the left window and a route will appear on the map.
    - The distance to enter in the yellow cell of the spreadsheet is found under the Directions tab all the way at the bottom of the open route under Route.
    - Clean up the route by removing the directions and associated markers (yellow boxes with two black lines), untick all of the boxes in the tab except for the Route box.
2. If you do not like the route chosen, then add markers at key positions on your preferred route by clicking on the thumbtack symbol and dropping the markers at the correct location. You can then map routes sequentially from the presentation position by right clicking the destination side and choosing "Directions to here" and right clicking the landmark side and clicking "Directions from here," then clicking on the magnifying glass to show the route.
    - The various elements can be hidden or shown by unticking or ticking the appropriate boxes under the Route tab to get one continuous marked route.
    - The format of the line or lines can be modified by right clicking on the line and choosing Properties. In Figure 1, the route color is changed to red, and the line thickness is increased.
3. To get a distance on the route from the presentation location, click on the ruler symbol on the top menu and open the Path tab. The scale units can be adjusted here. Once this tab is open, the cursor will change and you click once over your exact position in the building. Then click along the path noting the cumulative distances displayed in the Ruler tab.
    - Left clicking and holding down on the last position allows you to drag the place holder while dynamically displaying the distance. This allows you to exactly map evolutionary events from the spreadsheet. The distance units can be changed as you get further away (e.g., from feet to miles) from the presentation location.
    - Right clicking removes the last position.
    - Pointing to an existing position and holding down the left mouse button allows you to move that position.
4. When the distance is exactly correct for some event on the spreadsheet, click on the thumbtack on the top menu bar and place a marker on the route at that point.
    - The title and style can all be entered and adjusted by right clicking on the marker and selecting properties or in the box that appears when placing the marker.
    - To go back to the path mode, reclick on the Ruler tab on the menu bar.
5. All of the markers added to the map can be hidden from the Places tab. This allows you to sequentially add or remove markers for use at different times in the presentation.
6. PowerPoint images can then be made with screen grabs or selecting Copy Picture under the File menu in Google Earth, followed by editing in your preferred image program.
7. To save your work, right click on the Route in the Places tab and select Save to My Places. Individual Place markers can be saved the same way. The route and markers should then reappear next time you use Google Earth.

along a route that students are likely to have taken by car or train. The teacher (or perhaps the student as an assignment) first uses Google Earth to generate the route and determines the distances for the chosen events in time (see Figure 1). The route can be adjusted as described in Figure 1, step 2. The total distance is then put into an Excel spreadsheet to calculate the distances from a line of tape placed on the floor in the lecture hall to the various events in geologic time along the chosen route. The key evolutionary and/or geologic events are then mapped on the Google Earth map by placing markers along this route using the Ruler function. Screen captures of the maps can then be used to produce PowerPoint slides at key points along the way or the program itself might be used actively if there is an open fast internet connection.

One sometimes forgotten issue is the need to update the timeline in the spreadsheet. The best estimates of the dates for critical events in geologic time are topics of great interest and active research. Hence, it is a good idea to recheck the literature periodically to make sure that one is up-to-date with the current sequence and timing of events. I have provided a spreadsheet to convert time to distance with some key dates that I have accumulated (*www.soton.ac.uk/~jdparker/Google Earth timeline.xls*). I cannot guarantee that they will be accurate at the time of publication.

The presentation

To introduce the analogy, I begin by placing a piece of yellow tape on the floor in the front of the room and explain what I am doing. Here I give the rationale for why this analogy is better than the traditional clock analogy. From a lecture hall at the University of Southampton on England's southern coast, Big Ben in London is exactly 78.4 mi away and makes a good landmark for this exercise location (see Table 1). I then put up a map of southern England and ask students to raise their hands. I trace the path from Big Ben to our location and ask students to lower their hand when they think I have arrived at the stated event. The class's guess is when half the students have lowered their hands. This forces all of the students to participate, and after a couple of guesses, the class warms to the exercise with everyone participating. Students usually come close to the origin of life (the M25 ring highway around London) but almost always miss Eukaryotic cells (Basingstoke), the Cambrian explosion (around Winchester), and the extinction of the dinosaurs (just outside of town). I move on to show them a map with the key events marked. Figure 2 shows some typical screen captures with labels at various points from Table 1 along the timeline. Events closer and on campus include India uniting with Asia at walking distance on the edge of campus, and Hominids, our first upright walking ancestors, occurring across the street from the local pub. Obviously, the analogy lends itself to many opportunities for those who are comfortable with using humor in their teaching. The real lesson occurs inside the lecture hall where humans arise only 18 ft. (5.5 m) or so from the line and Neanderthals continue until 3 ft. (about 90 cm) from the line. I use a tape measure as a visual aid inside the lecture theater. It is worth pointing out that Biblical creationists place the origin of the Earth at about 6.5 in. (16 cm) from the line as opposed to the 78.4 mi. (126 km) to Big Ben. This emphasizes the difference between the view of creationists and science. The time of Christ occurs about 2 in. (5.4 cm) from the line. I end with the student life span being about 1/50th of an inch (0.5 mm) from the line and re-

TABLE 1

An example ideal scaled timeline.

Date	Event	Distance from line at presentation	
4.6 BYA	Earth formation	78.4 mi.	126 km
3.6 BYA	First life	61.4 mi.	98.7 km
2.7 BYA	Oxygen atmosphere	46 mi.	74 km
1.5 BYA	Eukaryotes arise	25.6 mi.	41.1 km
670 MYA	First Metazoan	11.4 mi.	18.4 km
542 MYA	Begin Cambrian	9.2 mi.	14.9 km
488 MYA	End Cambrian	8.3 mi.	13.4 km
375 MYA	First tetrapod	6.4 mi.	10.3 km
140 MYA	Angiosperms	2.4 mi.	3.8 km
25 MYA	First apes	2,223 ft.	678 m
10 MYA	India connects to Asia	890 ft.	271 m
6 MYA	Earliest Hominid	534 ft.	162 m
4.5 MYA	Ardipithecus	400 ft.	122 m
3 MYA	Lucy	267 ft.	81.3 m
1 MYA	Migration from Africa	89 ft.	27.1 m
200,000 yrs	Homo sapiens arise	17.8 ft.	5.4 m
34,000 yrs	Neanderthals go extinct	3 ft.	92 cm
6,000 yrs	Biblical age of Earth	6.4 in.	16.3 cm
2,000 yrs	Christ	2.1 in.	5.4 cm
18 yrs	Student age	1/50th of an inch	0.5 mm

Note: BYA = billion years ago; MYA = million years ago; yrs = years.

mind them to think about that when driving at 70 mph on the highway to London for 30 minutes through the prokaryotic world between Basingstoke and the M25.

The presentation length and level can be varied depending on the amount of detail the instructor wishes to cover. I have used this as a 10- to 25-minute section of larger lectures on evolution and have received outstanding feedback in comments from students and older adult public groups.

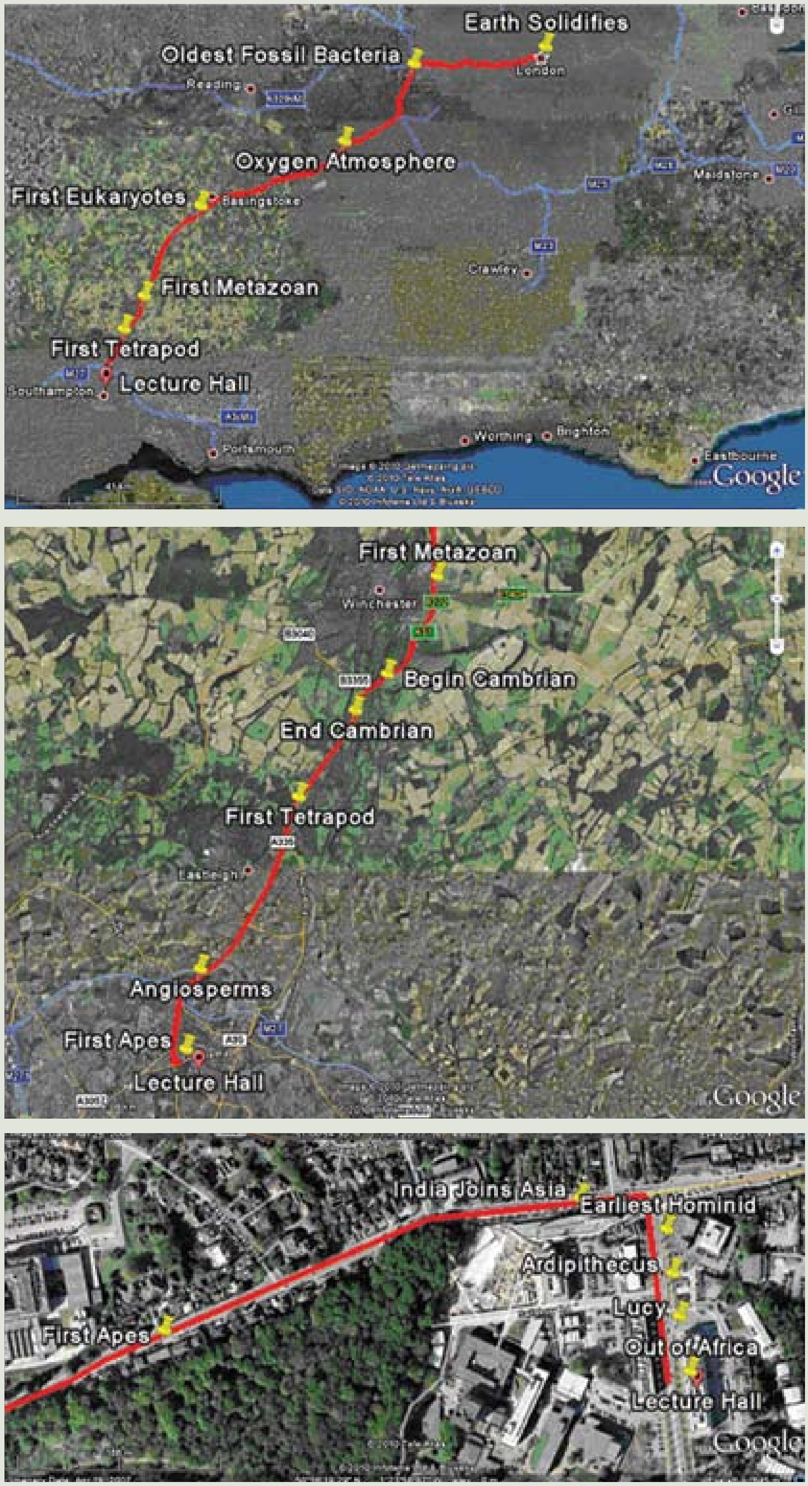
Discussion

There are very good reasons as to why this geographic analogy has proven so popular and effective. First and foremost, it avoids the pitfall of trading off the incomprehensibly large for the incomprehensibly small. By shortening geologic time too much, we lose the perspective of real experienced time by over compressing recent time. Getting it right requires aligning the length of time students can understand with a distance that students can reasonably see and experience. The result is a seamless linear scale from inside the room, to campus, through to the highway distances. This is not achievable in any other timeline analogy scale. Hence, this scale may be the only fit-for-purpose timeline scale for teaching both relative and absolute deep time.

The second reason the Google Earth analogy works is because humans are evolutionarily adapted to think in terms of geography. We are descended from hunter-gatherers and tend to have very good geographical awareness. Indeed, some memory competitors take advantage of this trait by using a spatial map (the journey method) to help remember playing card orders during competitive recall competitions (O'Brien 1993). Cars and trains have altered our perception of our modern territory and foraging areas, but we are still adapted to using landmarks to correctly perceive distances. At least one study on scale perception and teaching omitted this evolutionary explanation but did show that we tend to use physical movement and anchor points to understand scale (Jones and Taylor 2009). Thus, using local geographi-

FIGURE 2

Three screen captures of the example timeline at various scales.



cal landmarks takes advantage of this natural innate predisposition to achieve the learning objectives. This can also be highlighted in the introduction of the analogy if the topic is evolution.

Finally, by choosing a well-traveled route and relating the events to local landmarks, students can review and reexperience the analogy over and over throughout their time at university and beyond. This allows for constant reinforcement of the exercise. Walking to class or going home for break literally turns into a study exercise.

The customization of the analogy means that it can be used across cultures and continents. The example is given in southern England, but I can imagine that an upper limit of 100 to even 500 mi. might be used in parts of the United States and possibly even 500 to 1,000 mi. in Canada. In contrast, train-travel distances might be a more appropriate standard for India and European nations. Truly meaningful cultural and geographic- specific analogies can be constructed anywhere that is covered by Google Earth and where students are likely to have traveled more than 75 mi. (120 km).

It is important to note that perception of deep time is a conceptual form of learning (Sinatra, Brem, and Evans 2008). Meeting the learning objective of understanding deep time is not really quantifiable, but a matter of a Gestalt perception or feeling. Indeed, the first time I felt like I truly appreciated deep time was when constructing this timeline. The feedback from this analogy indicates that this objective is being met with many students and members of the public telling me they were "blown away" or indicating that this was the first time they really got the magnitude of time. Other comments received from course evaluations include the following:

- Particularly liked the last lecture with the visualisation of the timeline it made it a lot clearer to me.
- Really put the timescale into perspective, was enjoyable and I was amazed.

The first time that I used this timeline based on Google Earth, a specific question was included in the end of the course survey asking students to score this particular lecture on a scale of 1 to 5 (*very poor* to *very good*). It was scored at 4.5 with 59% giving the presentation a very good rating (61 students responding). I have only received one negative comment suggesting that I "was making fun of creationists" and was "too hard on them" during a discussion of the Biblical age of the Earth. Since then, I am very careful to emphasize that creationists find science just as outlandish to suggest that the world's age maps to 75 mi. away from the line instead of 6 in. The Biblical creation date and the contrast with the distance to the chosen landmark is a particularly important point to make as the scale problem has been identified as one of the great problems with convincing students of the validity of evolution (Hillis 2007; Cotner, Brooks, and Moore 2010). On such a timeline, the diversity of life simply could not have evolved within the times corresponding to inside the lecture hall. Evolution can only be intellectually accepted with a time scale extending nearly 100 mi. outside the lecture hall.

The concept of the great magnitude of geologic time is an absolutely critical component to understanding how Darwin's theory can explain the origin of species. The magnitude can be grasped by analogy, but only if the analogy is on a human experienceable scale. Teachers of evolution should therefore opt for such scales when using analogies of deep time (fractions of inches to hundreds of miles). As a lecturer, I found using Google Earth to make the slides a revelation for my own understanding of the magnitude of deep time. Having students make such timelines themselves is an obvious extension of this method that is likely to improve student understanding of this essential concept. ■

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