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The Earth Expansion Evidence

Ancient Life's Gravity and its Implications for the Expanding Earth

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Abstract. Galileo Galilei emphasised in the 17^{th} century how scale effects impose an upper limit on the size of life. It is now understood that scale effects are a limiting factor for the size of life. A study of scale effects reveals that the relative scale of life would vary in different gravities with the result that the relative scale of land life is inversely proportional to the strength of gravity. This implies that a reduced gravity would explain the increased scale of ancient life such as the largest dinosaurs. In this paper, various methods such as dynamic similarity, leg bone strength, ligament strength and blood pressure are used to estimate values of ancient gravity assuming a Reduced Gravity Earth. These results indicate that gravity was less on the ancient Earth and has slowly increased up to its present-day value. The estimates of the Earth's ancient reduced gravity indicated by ancient life are also compared with estimates of gravity for Constant Mass and Increasing Mass Expanding Earth models based on geological data. These comparisons show that the Reduced Gravity Earth model agrees more closely with an Increasing Mass Expanding Earth model.

Key words. Ancient gravity – Reduced gravity Earth – Scale effects – Expanding Earth

1. Introduction

Galileo Galilei (1638) was probably the first scientist to point out that larger animals need relatively thicker bones than smaller animals. He noted that the bones of very large animals must be scaled out of proportion in order to support the weight of the animal. This is because when any object increases in size its volume (l^3) increases quicker than its area (l^2), and its area increases quicker than its length (l). For example, a simple box which was doubled in length would be four times the area and eight times the volume of the original box. The leg stress in a large animal is proportionally more than a geometrically similar small animal because the weight of the large animal has increased quicker than its strength. This is commonly known as the scale effect.

To overcome this shortfall in strength with increased size, the legs of real large-scale animals generally tend to be proportionally thicker. Take for comparison the thigh bones of a deer, a rhinoceros and an elephant. As animals increase in scale the relative thickness of their legs is greater. The deer has the most slender legs, the rhinoceros relatively thicker ones, while the elephant's legs are thicker still to support its massive bulk. The elephant is near the upper size limit for land-based life.

The same basic principles can be seen in land-based animals, plants and flying birds. The largest insects have reached the upper size limit for creatures without bones. Mammals have reached the largest size for animals with bones and a complex four-chambered heart. Reptiles have reached the largest size for animals with bones and simple hearts. The largest plants have reached the upper limit in size and the largest birds have reached the upper lifting capacity of their wings. For every form of living creature there is an upper limit to how large it can be.

The scale effect means that gravity limits the scale of present-day land-based life. This has been well understood for many years by specialists in the field such as Thompson (1917), Schmidt-Nielson (1984) and others. The scale effect limit presents a difficult problem for ancient gigantic animals like dinosaurs. Over the years, many different solutions to the problem of their large scale have been suggested. Until at least the 1980s it was widely thought that large sauropods lived in water so the buoyancy effect permitted them to grow large (Schmidt-Nielson 1984), but this idea is now considered incorrect. Bakker (1986) was the main champion for the evidence that these large animals lived on land and his interpretation is widely accepted today. Hokkanen (1985) calculated a theoretical upper mass limit for an animal in present gravity that lay between 10^5 to 10^6 kg (10 to 100 metric ton) but also found the athletic ability of the largest animal to be so low that "a mass 10^6 kg allows a running speed of 6 km/h – a man could walk and overtake". Conversely, many paleontologists accept Bakker's (1986) understanding that sauropods were at least as athletic as modern elephants.

The concept that a reduced gravity in the past may have increased the relative scale of ancient life has been less well researched but has been considered by Kort (1949), Hurrell (1994, 2011), Mardfar (2000, 2011), Erickson (2001), Scalera (2002, 2004) and Strutinski (2011).

2. The relationship between relative scale and gravity

The relationship between relative scale and gravity can be examined using standard animals as shown in Fig.1. Imagine there are two animals of exactly the same shape, except that the larger one is twice the linear scale of the smaller animal. Under the same gravity, the stress in the larger animal's legs would be double the stress in the smaller animal's legs. This variation can be compensated for by adjusting the strength of gravity: if gravity was one half as strong for the larger animal, it would be four times as heavy. Both the small and large animals would have the same leg stress because of the difference in gravity. They would be dynamically similar despite their difference in size because of the variation in gravity.

In the above example the relative scale of life was increased because of the reduced force of gravity. This mathematical relationship between the scale of life and gravity can be defined as:

> *For a particular form of life the linear scale of land-based life is inversely proportional to the strength of the gravitational field* (Hurrell, 1994).

This can be represented in a formula as:

$$S_r = \frac{1}{g_r} \qquad (1)$$

where S_r is the relative scale of life, and g_r is gravity relative to the Earth's current gravity.

The effect of gravity on life's scale is a distinct mathematical relationship that affects the basic building blocks of animals – bones, ligaments, muscles and blood pressure. A reduced gravity reduces the force on any animal's bones, ligaments and muscles so they can all be thinner and weaker for a particular scale of life. Blood pressure is also reduced in a weaker gravity since blood pressure is the hydrostatic weight of blood (mass × gravity).

This implies that the scale of ancient life was shifted towards a larger size in a reduced gravity. The most obvious result of this scale shift is gigantic dinosaurs with masses equal to several elephants but the effects are also plain on smaller animals as well. An elephant-sized dinosaur is noticeably more active and dynamic than any elephant because the dinosaur evolved to live in a reduced gravity.

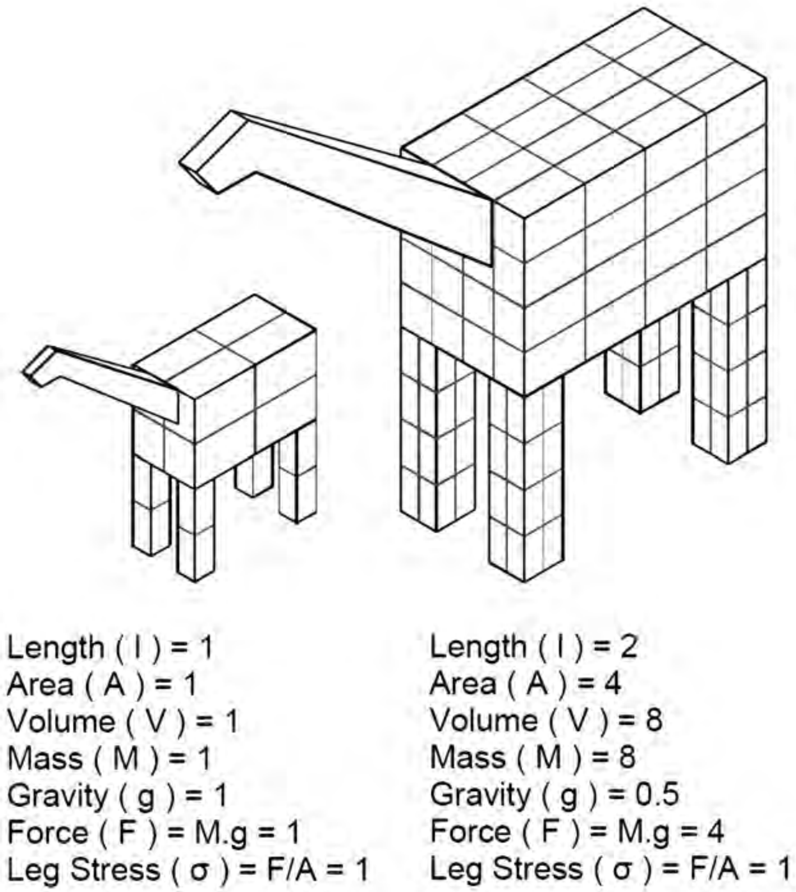

Fig. 1. The force on geometrically similar animals in a different gravity illustrates the relationship between life's scale and gravity. An animal's leg stress is due to the force of gravity. If gravity is halved then the large animal can double its linear size while its leg stress will still be the same as the small animal's leg stress.

Formula (1) can be transposed to provide an estimate of ancient gravity based on the relative scale of ancient life:

$$g_r = \frac{1}{S_r} \tag{2}$$

This paper calculates values for reduced gravity and weight on an assumed Reduced Gravity Earth using ancient life and introduces 'shorthand descriptions' to denote this throughout the paper. For example, gravity and weight 300 million years ago may be defined as gravity$_{300}$ or g_{300} and weight$_{300}$ or w_{300}. Specific values of reduced gravity are also given a 'shorthand description' so that, for example, a reduced gravity of 60% the present gravity is given as $0.6g$.

The values of calculated ancient gravity also have a 'confidence index' allocated which is a method of assigning a numeric value to the confidence in the results. Two methods are used to allocate a 'confidence index'. The first method is to define a 'reconstruction confidence index' and a 'dynamic similarity confidence index' and calculate a 'total confidence index' by multiplying the two results together. The

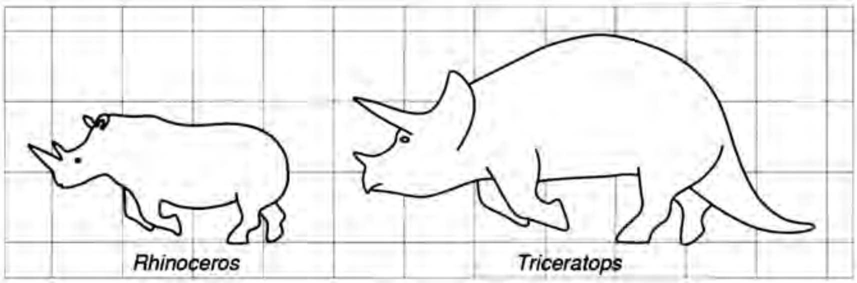

Fig. 2. A modern rhinoceros and *Triceratops* both moving and acting in a dynamically similar manner.

'reconstruction confidence index' denotes confidence in the original reconstruction of the ancient animal. The 'dynamic similarity confidence index' denotes confidence that the animal moves and acts in a similar manner to the animal used for comparison. The second method used to define a 'total confidence index' utilises the ratios of the calculated values of Minimum gravity and Maximum gravity when they are available. The examples given throughout the paper illustrate these methods more fully.

Various methods, such as dynamic similarity, leg bone strength, ligament strength and blood pressure are used to estimate reasonably accurate values of ancient gravity. Numerous comparisons could be used to calculate ancient gravity but just a few examples are given to illustrate the principles in more detail.

3. Dynamic similarity

Palaeontologists have noted that large dinosaurs appear to be dynamically similar to smaller animals alive today (Alexander, 1983, 1989; Bakker, 1986).

In a reduced gravity this increase in the relative scale of life is exactly what we would expect. The relative scale of dynamically similar ancient and modern life can therefore be used to estimate the gravity at the time of ancient life. In practice, the dynamic similarity of the largest life is the most easy to compare since this life defines the upper size limit for a particular form of life in a defined gravity.

Triceratops – A *Triceratops* would appear to move like a buffalo or a present-day rhinoceros suggesting that *Triceratops* would be able to move and gallop in a dynamically similar way to a rhinoceros as shown in Fig.2. *Triceratops* lived about 68 to 65 million years ago and is about 1.67 times the size of a rhinoceros, so if both animals are moving in a dynamically similar way then the value of gravity about 66 million years ago can be calculated using formula (2):

$$\text{gravity}_{66} = 1/1.67 = 0.6g$$

The *Triceratops* is a well-known animal so the 'reconstruction confidence index' is 0.9 out of a maximum 1. The *Triceratops* is similar in general appearance to a rhinoceros although *Triceratops* also has a large tail so the 'dynamic similarity confidence index' may be 0.6. The 'total confidence index' is therefore $0.9 \times 0.6 = 0.54$. To sum up, about 66 million years ago gravity was approximately 60% of our present gravity with a confidence index of 0.54.

Ancient Dragonflies – Dragonflies similar to modern forms were present in the Carboniferous, dating from about 300 million years ago. These dragonflies were usually large and occasionally gigantic in size. The *Muséum national d'Histoire naturelle* in Paris contains the only two known examples of the famous giant dragonfly, *Meganeura monyi*. With a wingspan of about 75 cm, it is still claimed by some

Fig. 3. A life-size reconstruction (72 cm wingspan) of *Meganeuropsis permiana* by Werner Kraus for the University Museum of Clausthal-Zellerfeld. © Werner Kraus 2003.

authorities to be the largest known insect species to ever fly. This wingspan of 75 cm is gigantic compared to that of 19 cm for one of the largest modern species of dragonfly, the Giant Hawaiian Darner dragonfly, *Anax strenuus*.

Applying formula (2) to the ancient and modern forms of dragonflies gives a value for gravity 300 million years ago:

$$\text{gravity}_{300} = 1/3.95 = 0.25g$$

Gravity 300 million years ago was 25% of today's gravity from a simple dynamic similarity comparison. There are some fundamental assumptions used with this comparison; both the ancient dragonfly fossils and the largest modern species of dragonfly are assumed to have reached the largest size possible for a dragonfly in their respective gravities, and both the ancient and modern dragonfly are assumed to be dynamically similar and have followed similar lifestyles.

How accurate are these assumptions? The ancient dragonfly which is commonly accredited as being the largest has several rivals which are very close to the famous giant dragonfly, *Meganeura monyi*. Examples of these are *Meganeuropsis americana* and *Meganeuropsis permiana*, as shown in Fig.3, from the Lower Permian fauna of Elmo. Given the fact that these are both very close in size to *Meganeura monyi* it would seem likely that this is about as large as these ancient dragonflies grew, even if there is some disagreement about which was the largest.

A similar argument applies to the largest present-day dragonfly. Although the Giant Hawaiian Darner dragonfly is the largest recorded size of dragonfly there are other species approaching this size: the Giant Petaltail dragonfly *Petalura ingentis-*

sima has a wingspan of approximately 16 cm, for example. It would seem that we can safely assume that the sizes of the largest ancient and modern dragonflies are sufficiently accurate to calculate gravity 300 million years ago.

Is there any other way to check the results? Since there are still dragonflies around today there is an interesting method of doing this. Experiments performed by Marden (1987) loaded dragonflies with weights to measure the maximum amount that a range of dragonflies could lift. The largest dragonfly that Marden experimented with was *Anax junius*, which is commonly known as the Green Darner Dragonfly. The five individuals measured had an average mass of 0.9752 grams and an average maximum lifting force of 2.58 grams with an average wingspan of 10 cm. Comparing these dragonflies to the ancient dragonfly *Meganeura monyi* would give a scaling factor of 75/10 = 7.5. Using the scale effect to calculate the weight and lifting force of the ancient dragonfly assuming it was dynamically similar to the modern dragonfly gives:

$$W_s = (W_o^{1/3} \times s)^3 = (0.9752^{1/3} \times 7.5)^3 = \\ = 411 \text{ g},$$

and

$$L_s = (L_o^{1/2} \times s)^2 = (2.581^{1/2} \times 7.5)^2 = \\ = 145 \text{ g},$$

where W_s is the scaled weight, W_o is the original weight and s is the linear scaling factor applied. L_s is the scaled lifting force, L_o is the original lifting force and s is the scaling factor used. Obviously the scaling factor will be the same to calculate the scaled weight and the scaled lifting force.

This is clearly a dragonfly that couldn't fly in our present gravity since it weighs 411 grams but can only produce a lifting force of 145 grams. We could reduce the weight of the dragonfly by assuming that gravity was $0.35g$ so that the lifting force was exactly the same as the dragonfly's weight. This gives a maximum possible force of gravity 300 million years ago as $0.35g$. Even this seems beyond reasonable limits since it is difficult to imagine a dragonfly that didn't have any power reserves. It doesn't seem a realistic proposal especially if we consider that dragonflies are predators that need to capture small insects to survive and the female dragonfly must also mate in flight and then lay its eggs in water – a sudden gust of wind would drown our large dragonfly. It probably means that these calculations represent an absolute size limit that could not be exceeded and was unlikely to be reached in practice.

The 'reconstruction confidence index' must be good, perhaps as high as 0.9, since the fossil dragonfly *Meganeura monyi* looks like a larger version of a modern-day dragonfly. The 'dynamic similarity confidence index' must be high as well, perhaps even 1, for similar reasons. Based on the fossil *Meganeura monyi*, the 'total confidence index' that gravity was 25% of the present value 350 million years ago would be 0.9.

4. Leg bone strength

Dinosaur reconstructions are based on fossil bones fitted together to form complete skeletons. It is these skeletons that in turn tell us the size of the dinosaurs. Many of the best known skeletons have been made from bones that have been found together, apparently from one individual animal, so palaeontologists are reasonably certain that they are a realistic interpretation of that animal.

Obviously, skeletons alone cannot give an animal's weight directly. One method to infer the weight of a living dinosaur is to create life-like models of the reconstructed animals although the accuracy of these reconstructions relies on the skill of the modeller.

Another method of estimating dinosaurs' weight studied by Anderson et al (1985) is to use leg bone dimensions directly to estimate the live weight of the animal. Bone is not the inert material many people believe; it is a living dynamic tissue that is continually being modified and replaced. Bone can become stronger after exercise or can waste away through periods of inactivity. Astronauts and cosmonauts have particular problems in space because their bones become weaker when they are not subjecting them to the stress of gravity. Animals' bones, and in particular their leg bones, grow thicker depending on how much an animal weighs.

Anderson, a US zoologist, had a long interest in the size of animals' bones. Anderson, together with a team, studied the bones of a range of mammals to see if there were any rules that would allow them to estimate the mass of an animal from just its leg bones. This would be very useful for extinct animals such as dinosaurs. The University of Florida where Anderson worked had a large collection of mammal skeletons complete with records of the masses of these animals when they were alive. That particular collection included only a few really large mammals but another member of the team, Hall-Martin, who worked at the Kruger National Park in South Africa, was able to measure the bones of animals shot in the Park. The final member of the team was Russell, a Canadian dinosaur specialist.

The Anderson team chose to study the major leg bones which are often well preserved in otherwise incomplete fossils. Leg bones carry the weight of animals' bodies so would seem to be the obvious choice. The bone lengths would be prone to errors since some animals have long spindly legs but other animals have short stubby legs. A good indication of the mass of present-day animals is the circumference of the upper leg bones – the humerus and the femur. The humerus is the upper arm bone in us but in the front legs in four-footed animals. The femur is our upper leg bone – the thigh bone – or in the back leg in four-footed animals. The bones were measured where they were the thinnest, and so the weakest, usually about half way along the length of the bones. These two circumferences were then added together to give the total circumference of the humerus and femur. The circumference of either the humerus or the femur could have been used alone but this might have lead to error since some animals place more weight on the front or the rear legs. The use of the front and back legs taken together tends to cancel out this error.

Table 1 and Fig.4 present raw data of animal weight and bone dimensions kindly supplied by Alexander (1995). The new raw data is substantially similar to the original Anderson team data and shows the consistency of the concept. If you look at the Fig.4 graph of weight-to-leg bone circumference for a range of four-footed animals you will notice that the graph is plotted on a log scale so that a whole range of different-sized animals from mice to elephants can easily be shown on the one graph. The points on the graph – which are the plotted weights of various animals – form a more or less straight band across the graph. The Anderson team fitted a line to the points they had based on statistical analysis and estimated that the best line that can be fitted to these points was defined by the equation:

$$M = 0.000084 \cdot c^{2.73},$$

where M = Body mass in kg and c = Total of Humerus and Femur circumference in mm. This equation can now be used to estimate the body mass of any animal from just the humerus and femur bones. The accuracy of the data can be checked and two other lines have been added to the Fig.4 graph to show how a variation of ±30% would affect the results. Virtually all the plotted animals' points lie within this error band with many much closer than this. The formula is based on four-footed animals so it would seem reasonable to apply it to four-footed dinosaurs and the error should certainly be within the normal error band.

As two-legged animals would need a different formula, the Anderson team modified the four-footed equation so that only

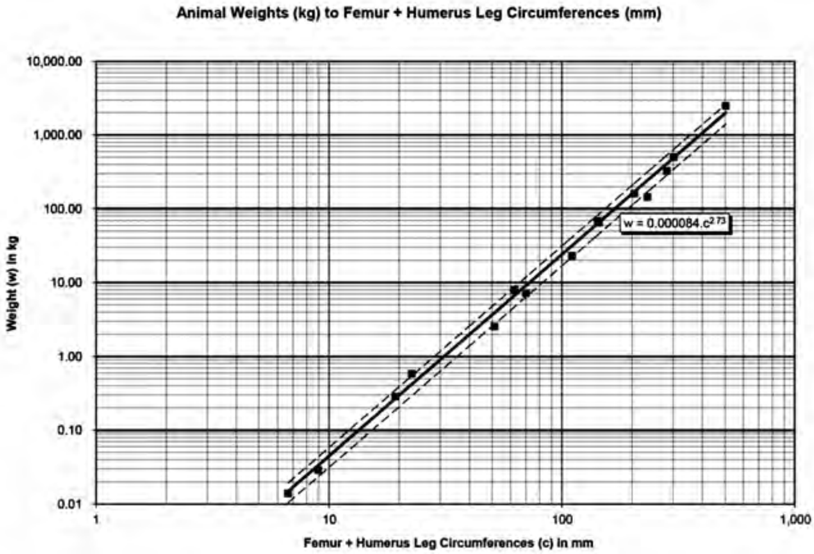

Fig. 4. Graph of mammals' leg dimensions plotted against weight as detailed in Table 1.

Measured Weight (kg) to Leg Diameter (mm)				
	Weight (kg)	Femur Dia (mm)	Humerus Dia (mm)	Fd + Hd Cir (mm)
Fieldmouse	0.014	1.07	1.05	6.66
Mouse	0.029	1.43	1.42	8.95
Rat	0.285	3.30	2.80	19.16
Ferret	0.580	3.80	3.40	22.62
Cat	2.540	7.70	8.60	51.21
Jackal	7.200	10.30	11.90	69.74
Fox	8.000	9.40	10.50	62.52
Dog	23.000	15.80	19.30	110.27
Warthog	65.000	21.50	24.40	144.20
Grant's Gazelle	68.000	21.00	24.20	142.00
Lion	145.000	30.30	43.50	231.85
Wildebeest	161.000	29.80	35.30	204.52
Camel	326.000	41.40	48.50	282.43
Buffalo	500.000	46.20	49.50	300.65
Elephant	2,500.000	72.40	88.20	504.54

Table 1. Raw data of mammals' leg dimensions for various weights.

the femur circumference is required. Their equation for two-legged animals is:

$$M = 0.00016 \cdot c^{2.73},$$

where M = Body mass in kg and c = Femur circumference in mm.

One use of these equations would be to calculate the weight of extinct animals and the Anderson team applied their equations to a number of dinosaurs. One would expect the results to have certainly been within ±30% and in most cases a lot more accurate than this. Most dinosaurs *should have* been close to the best fit line. But the results indicated dinosaurs were much lighter than anyone had ever thought possible.

Since the bone results were first published in 1985 the weights of dinosaurs based on volume methods have been reduced to try to agree with these super-light dinosaurs. However, this raised questions. The weight for *Diplodocus*, for example, was calculated at 5.8 tonnes from bone dimensions, which is similar to a modern-day elephant. This doesn't seem reasonable if you compare an elephant skeleton alongside a *Diplodocus* skeleton because the *Diplodocus* skeleton is much larger.

As the two methods give very different results some palaeontologists have advised abandoning the use of the formula based on leg bones since they cannot get dinosaurs light enough to agree with the bone weight calculations. The differences are so great for large bipeds that Hutchinson et al (2007) concluded that:

> *...it is almost certain that these scaling equations greatly underestimate dinosaur body masses ... Hence, we recommend abandonment of their usage for large dinosaurs.*

These results are fundamental to the reduced gravity hypothesis. The Reduced Gravity Earth theory predicts that leg bone strength will be weaker in a reduced gravity and this is exactly what we see in practice. The body mass estimates based on volume methods greatly exceed those based on leg bone strength because they assume gravity was the same in the past. This variation between body mass estimates and leg bone strength can therefore be used to calculate ancient gravity when ancient life was alive.

Tyrannosaurus rex – One meat-eating type of dinosaur that shows a variation between the weight calculated from model volumes and the expected weight from bone calculations is *Tyrannosaurus rex*, as shown in Table 2. Some of the estimated weights for *Tyrannosaurus rex* are from different specimens so it would be expected that these may be different size animals which would have different weights. The *Tyrannosaurus rex* examined by Henderson and Snively (2003) is nicknamed 'Sue' and is the largest *Tyrannosaurus rex* found to date. If only one specimen (MOR 555) is considered its weight based on the volume method only varies between 5.4 to 6.6 metric tonnes when studied by three different research teams, Paul (1997), Farlow et al (1995) and Hutchinson (2007). This same specimen has also been used to calculate its weight based on its bone dimensions by two research teams, Anderson et al (1985) and Campbell & Marcus (1993).

The bone dimension calculation indicates the legs of *Tyrannosaurus rex* only evolved to carry an animal that weighed between 3.5 to 4.5 metric tonnes while the volume method gives a mass between 5.4 to 6.6 tonnes. Using an average of these results to calculate gravity 65 million years ago:

$$\text{gravity}_{65} = \frac{\text{Calculated weight}}{\text{Volume Mass}} = \frac{4.0}{6.0} =$$

$$= 0.66 \text{ g}$$

The absolute maximum and minimum values of gravity can be calculated from the extremes of the weight estimates with the absolute maximum and minimum being 0.83g and 0.53g about 65 million years ago. The confidence index can be calculated from the variation in the results. So confidence index = Min gravity / Max gravity = 0.53/0.83 = 0.63.

Weight estimates in tonnes for Tyrannosaurus rex		
from models		
Colbert (1962)	7.7	
Alexander (1985)	7.4	
Paul (1987)	5.7	
Paul (1997)	5.4	Specimen MOR 555
Farlow et al (1995)	5.4-6.3	Specimen MOR 555
Henderson (1999)	7.2-7.9	
Christiansen (1998,1999)	6.2-6.3	
Seebacher (2001)	6.7	
Henderson, Snively (2003)	10.2	"Sue" specimen
Hutchinson (2007)	5.4-6.6	Specimen MOR 555
from leg stress		
Anderson at al (1985)	4.5	Specimen MOR 555
Campbell, Marcus (1993)	3.5	Specimen MOR 555

Table 2. Comparison of weight estimates in tonnes for *Tyrannosaurus rex* based on volume mass estimates from models and leg stress estimates on bone.

5. Ligament strength of Diplodocus

Present-day horses and cattle have thick ligaments called the *ligamentum nuchae* running along the back of their necks to support their heads.

The sauropod *Diplodocus* has neck vertebra with V-shaped neutral spines as shown in Fig.5 and Alexander (1989) suggested that the V was filled by a ligament that ran the whole length of the neck and back into the trunk of the animal's body. The ligament would have supported the head and neck while allowing the dinosaur to raise and lower its head. Alexander calculated that the mass of the head and neck of *Diplodocus* would have been about 1340 kg. The weight of the neck and head acts 2.2 metres from the joint and the ligament tension acts 0.42 metres from the pivot of the joint so by the principle of levers the tension that would be needed to balance the weight to the neck and head would be $2.2 \times 13400/0.42 = 70000$ Newton.

The cross-sectional area of the ligament was estimated to be 40000 sq mm and from this it can be calculated that the stress for a force of 70000 Newton would be 1.8 Newton per square mm. This is more than the stress in the *ligamentum nuchae* of deer with its head down and the ligament fully stretched (which is about 0.6 Newton per square mm). It would be enough or nearly enough to break the ligament.

Stevens and Parrish (1999) suggested that the problem of the weak neck ligaments could be overcome if a sauropod's neck was imagined as a stiff, almost self-supporting structure where the neck vertebrae overlapped each other by around 50% to provide additional support. They built a computer model of *Diplodocus* in a neutral pose with its long neck at about shoulder height dipping slightly towards the ground. This depiction of a stiff-necked *Diplodocus* with its head held permanently low removed the problem of a weak neck ligament as well as the problem of high blood pressure if the neck was held high.

These stiff-necked reconstructions were generally accepted since they seemed to provide answers to real questions and

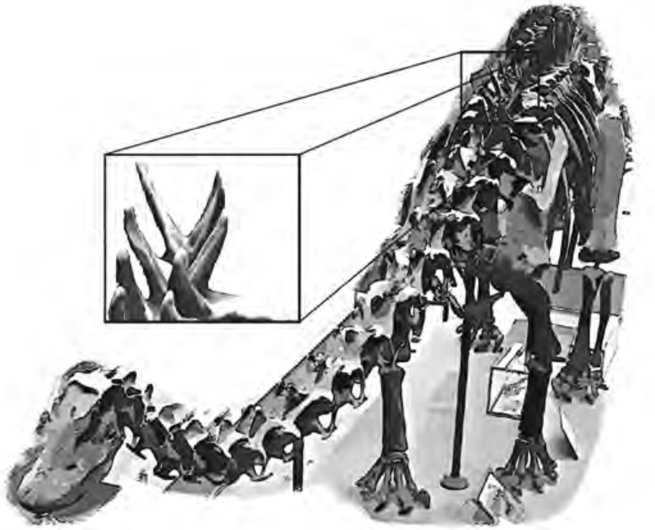

Fig. 5. V-shaped neck vertebra probably held the neck ligament used to keep Diplodocus's neck erect and this enables the ligament's size to be estimated.

Diplodocus is now mostly depicted with a stiff, relatively useless long neck that it couldn't lift to reach the higher plants. Many museums around the world and TV series like *Walking with Dinosaurs* show *Diplodocus* like this even though some paleontologists disputed this view (Bakker 1986).

A more recent study by Taylor et al (2009) presented additional arguments against these stiff-necked reconstructions and concluded that:

> *Unless sauropods carried their heads and necks differently from every living vertebrate, we have to assume that the bases of their necks were habitually curved upwards, ... In some sauropods this would have meant a graceful, swan-like S-curve to the neck, and a look quite different from the recreations we are used to seeing today.*

The problems encountered with *Diplodocus's* neck only occur because it is assumed that gravity was the same in the past. The Reduced Gravity Earth theory predicts that the neck ligament would be thinner in a reduced gravity and this is exactly what we see in practice.

Due to a reduced gravity the actual weight of *Diplodocus's* neck 150 million years ago would be:

$$\text{weight}_{150} = \text{Mass} \times \text{gravity}_{150}.$$

The weight of the neck and head still acts 2.2 metres from the joint and the ligament tension acts 0.42 metres from the pivot of the joint so by the principle of levers the tension that would be needed to balance the weight of the neck and head would be:

$$\text{Force} = 2.2 \times \text{Mass} \times \text{gravity}_{150}/0.42.$$

Also,

$$\text{Force} = \text{stress} \times \text{area},$$

so, rearranging to obtain gravity 150 million years ago:

$$\text{gravity}_{150} =$$

$$= \text{stress} \times \text{area} \times 0.42/2.2 \times \text{Mass} =$$

$$= 0.6 \times 40000 \times 0.42/2.2 \times 1340 =$$

$$= 3.4 \text{ m/s}^2.$$

This 3.4 m/s^2 calculated value of gravity 150 million years ago is much smaller than the present-day value of 9.81 m/s^2. How accurate is this value of gravity? There are a number of variables that might be different from the initial assumptions used; the ligament could be larger if it expanded outside the V-shaped neck bones, the force of the neck's weight would be lower if *Diplodocus* held its neck more upright, and additional muscles or ligaments might provide additional support. If the neck was held at a 45 degree angle the downward force of the neck would be reduced by 0.707. The ligament could easily be half as large again if it extended outside the V-shaped neck bones, increasing the area of the ligament to 60,000 sq mm. So:

$$\text{gravity}_{150} =$$

$$= \text{stress} \times \text{area} \times \frac{0.42}{2.2} \times \text{Mass} \times 0.707 =$$

$$= 0.6 \times 40000 \times \frac{0.42}{2.2} \times 1340 \times 0.707 =$$

$$= 7.25 \text{ m/s}^2.$$

The results give a value for gravity 150 million years ago as somewhere between 34% to 72.5% of the present gravity with the 'best guess' 53% of present gravity. The confidence index can be calculated from the variation in the results. If the Minimum and Maximum gravity was identical then our confidence index would be 1. So confidence index = Min gravity / Max gravity = 0.34 / 0.725 = 0.47.

6. Blood pressure of Brachiosaurus

Because of its long neck the giraffe has the maximum hydrostatic blood pressure of any animal alive today. This high blood pressure seems to be about the maximum possible since the giraffe needs to use extreme measures to maintain it. Because the central blood pressure is high the heart's muscle has to be strong and a giraffe's heart can weigh up to 10 kg and measure about 60 cm long. The heart of an adult giraffe is about 2% of its body weight whereas in people it's only about half a percent. Giraffes have arterial blood pressures of 25 kPa at the bases of their necks whilst standing. By extrapolation, the pressure in the heart must exceed 30 kPa which is about double the normal pressure in a mammal.

Brachiosaurus lived in the Late Jurassic to Early Cretaceous, about 145 million years ago. It is generally reconstructed with its neck sloping steeply up, in a giraffe-like posture so the brain of *Brachiosaurus* was about 7.9 metres above its heart as shown in Fig.6. Calculations assuming our present gravity reveal that the total pressure difference between the brain and the heart would be 8590 kPa.

These problems of high blood pressure would not exist on a Reduced Gravity Earth because blood pressure is lower in a reduced gravity. Blood pressure is proportional to blood mass, gravity and height, so it is possible to estimate ancient gravity by comparing the blood pressure in ancient life with the blood pressure in modern life.

The hydrostatic pressure difference between the blood in the brain and the heart can mostly be defined as the hydrostatic head in metres. The hydrostatic pressure at the base of the *Brachiosaurus's* neck 145 million years ago can be calculated by:

$$\text{Hydrostatic Pressure} =$$

$$= \text{blood density} \times \text{gravity}_{145} \times \text{height}.$$

In a reduced gravity the hydrostatic pressure would be reduced because the weight of the column of blood would be less and this would allow a

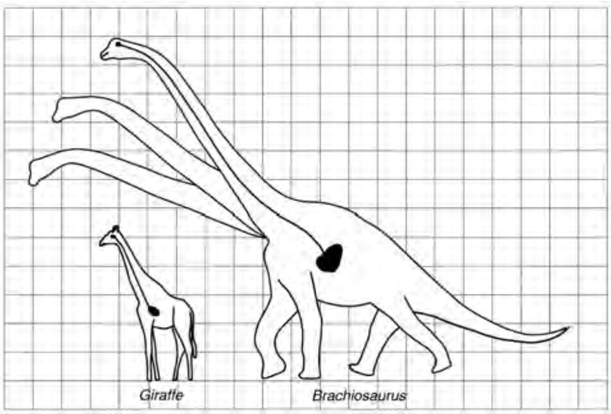

Fig. 6. The position of the head above the heart determines the blood pressure, or the hydrostatic head, at the heart for a giraffe and Brachiosaurus.

Brachiosaurus's neck to become much longer than today's giraffe. Blood is an incompressible fluid whose density would not vary in a different gravity so it seems safe to assume that the density of dinosaur blood was the same as giraffe blood. A large giraffe about 5.5 metres tall would hold its head 2.8 metres above its heart so the hydrostatic head in its heart would be 2.8 metres.

The assumption that the blood pressure above the heart of both the giraffe and *Brachiosaurus* is the maximum that the various tissues can withstand enables a calculation of the value of gravity when *Brachiosaurus* lived. We know:

Brachiosaurus Hyd. Pressure =

$$= \text{gravity}_{145} \times \textit{Brachios.}\ \text{Neck Height}$$

and

Giraffe Hyd. Pressure =

$$= \text{gravity} \times \text{Giraffe Neck Height}$$

so,

$$\text{gravity}_{145} = \frac{\text{Gir. N. Height}}{\textit{Brach.}\ \text{N. Height}}\ \text{gravity} =$$

$$= \frac{2.8}{7.9} \times \text{gravity} = 0.35\ \text{g}.$$

Using the lowest neck height which seems possible gives a hydrostatic head of 3.9 metres. Using this hydrostatic head would give:

$$\text{gravity}_{145} = \frac{\text{Gir. N. Height}}{\textit{Brach.}\ \text{N. Height}}\text{gravity} =$$

$$= \frac{2.8}{3.9} \times \text{gravity} = 0.72\ \text{g}.$$

My own 'best guess' about the position of the neck for *Brachiosaurus* is that it was somewhere between the two extremes. This intermediate position gives a hydrostatic head of 5.9 metres, which in turn would predict gravity to be:

$$\text{gravity}_{145} = \frac{\text{Gir. N. Height}}{\textit{Brach.}\ \text{N. Height}}\text{gravity} =$$

$$= \frac{2.8}{5.9} \times \text{gravity} = 0.48\ \text{g}.$$

So using the method of equating the blood pressure in the long neck of Brachiosaurus to a giraffe, gravitational acceleration is calculated somewhere between 35% to 72% of our present gravity 145 million years ago, with the 'best guess' value working out at 48% of our present gravity.

Common Name	Time (MYA)	Calculated Relative Gravity	Confidence Index	Estimation Method
Scorpion	420	0.23	0.70	Dynamic Similarity
Dragonfly	300	0.25	0.90	Dynamic Similarity
Plateosaurus	210	0.49	0.40	Leg Bone Strength
Diplodocus	150	0.51	0.77	Leg Bone Strength
Allosaurus	150	0.50	0.55	Leg Bone Strength
Diplodocus	150	0.53	0.47	Neck ligament
Apatosaurus	150	1.10	0.03	Leg Bone Strength
Brachiosaurus	145	0.48	0.63	Blood Pressure
Brachiosaurus	145	0.56	0.50	Leg Bone Strength
Brachiosaurus	145	0.45	0.36	Dynamic Similarity
Crocodile	110	0.53	0.90	Dynamic Similarity
Pterandon	70	0.65	0.54	Dynamic Similarity
Quetzalcoatus	70	0.59	0.16	Dynamic Similarity
Tyrannosaurus	66	0.66	0.63	Leg Bone Strength
Triceratops	66	0.60	0.54	Dynamic Similarity
Dasornis	50	0.68	0.64	Dynamic Similarity
Andrewsarchus	38	0.75	0.40	Dynamic Similarity
Brontotherium	35	0.75	0.72	Dynamic Similarity
Baluchitherium	25	0.72	0.72	Dynamic Similarity
Crocodile	20	0.53	0.18	Dynamic Similarity

Table 3. Table of the variation of Earth's gravity over hundreds of millions of years based on various comparisons of ancient and modern life.

7. Ancient gravity results

The calculated values of ancient gravity based on various animals using dynamic similarity, leg bone strength, neck ligament strength and blood pressure are reproduced in Table 3 and Fig.7 in order to gain an overview of the results.

Many forms of life can be used to calculate ancient gravity using the methods outlined in this paper. Table 3 includes calculated estimates for ancient gravity based on the dynamic similarity method for an ancient Scorpion, a Dragonfly, *Brachiosaurus*, two Crocodiles, *Pterandon*, *Quetzalcoatus*, *Triceratops*, *Dasornis*, *Andrewsarchus*, *Brontotherium* and *Baluchitherium*, and also based on leg bone strength for *Plateosaurus*, *Diplodocus*, *Allosaurus*, *Apatosaurus*, *Brachiosaurus* and *Tyrannosaurus*.

The graph in Fig.7 shows the 'best guess' value as circular dots of various sizes in order to represent the gravity value that has been calculated. It is notable that the dots representing gravity show a general trend of gravity gradually increasing over hundreds of millions of years.

Many of the distinct methods of calculating gravity give very similar values. If one animal which was subjected to a number of these calculation methods is taken as an example, such as *Brachiosaurus*, we can clearly see the similarity of the results. Dynamic similarity gives $0.45g$, leg bone strength $0.56g$ and blood pressure $0.48g$. These 'best guess' values all give results which are in broad agreement with each other even though they use different methods to calculate ancient gravity.

Comparing different animals to one another in the same time period also gives broad agreement for the 'best guess' value. Dissimilar animals that were alive about 150 million years ago such as *Brachiosaurus*, *Allosaurus* and

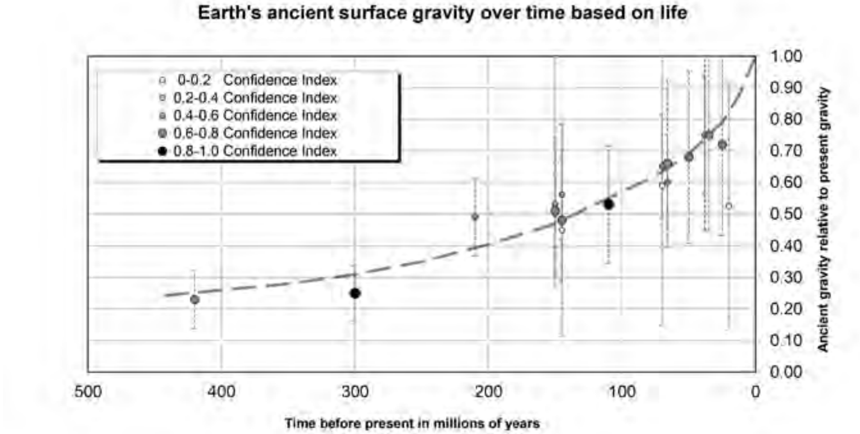

Fig. 7. Graph of the variation in Earth's gravity over hundreds of millions of years based on the various comparisons of ancient and modern life listed in Table 3.

Diplodocus also all give values for gravity which are in broad agreement with each other. Animals which were alive at other times give different values for gravity.

One element that needs to be considered for the confidence index is the variation in size naturally seen in the living animals of today. If the elephant is taken as an example, there is a wide variation in the size of elephants as a group. An African male elephant tends to be the largest at over 4 metres tall but the African female elephant is usually slightly smaller and the Asian female elephant smaller still at just over 3 metres tall. We see a general variation from about 3 to 4 metres in height in the largest animals alive today. If we assume an average height of 3.6 metres for the average African elephant then a reasonable variation ±10% would give a size range of about 3.2 to 3.9 metres for our sample. The same, or an even greater, variation in size was probably true for the dinosaurs and other prehistoric life. It is possible to remove that variation in our living model since we know what the average size is, but it is more difficult to remove this source of error in the extinct animal since there is such a small sample of fossils making it difficult to say if the living animal was a large or small member of the species. Because of this I believe that even the best possible calculation of gravity from ancient life would only be within ±15% of the true value at best and possibly much worse than this.

In the graph the 0.8-1 confidence index has been shown as the largest and blackest of the dots. The size and blackness of the dots reduce down as the confidence reduces until the 0-0.2 confidence index dots are the smallest and faintest of all. Vertical dotted lines are also shown coming out of all the dots and these are a further attempt to display this possible error on the graph. The values used for the error bars have therefore been set at: ±15% for 0.8-1 confidence index, ±20% for 0.6-0.8 confidence index, ±25% for 0.4-0.6 confidence index, ±30% for 0.2-0.4 and ±35% for 0-0.2.

The final element of the graph is a theoretical line to show how gravity may have varied over time from 300 million years ago up to the present day. It is interesting to note that this gravity line lies well within the error bars of the calculated values of gravity and even the estimates with the lowest confidence index are still within the error bars. In general, life indicates that gravity was less on the ancient Earth and has slowly increased up to its present-day value.

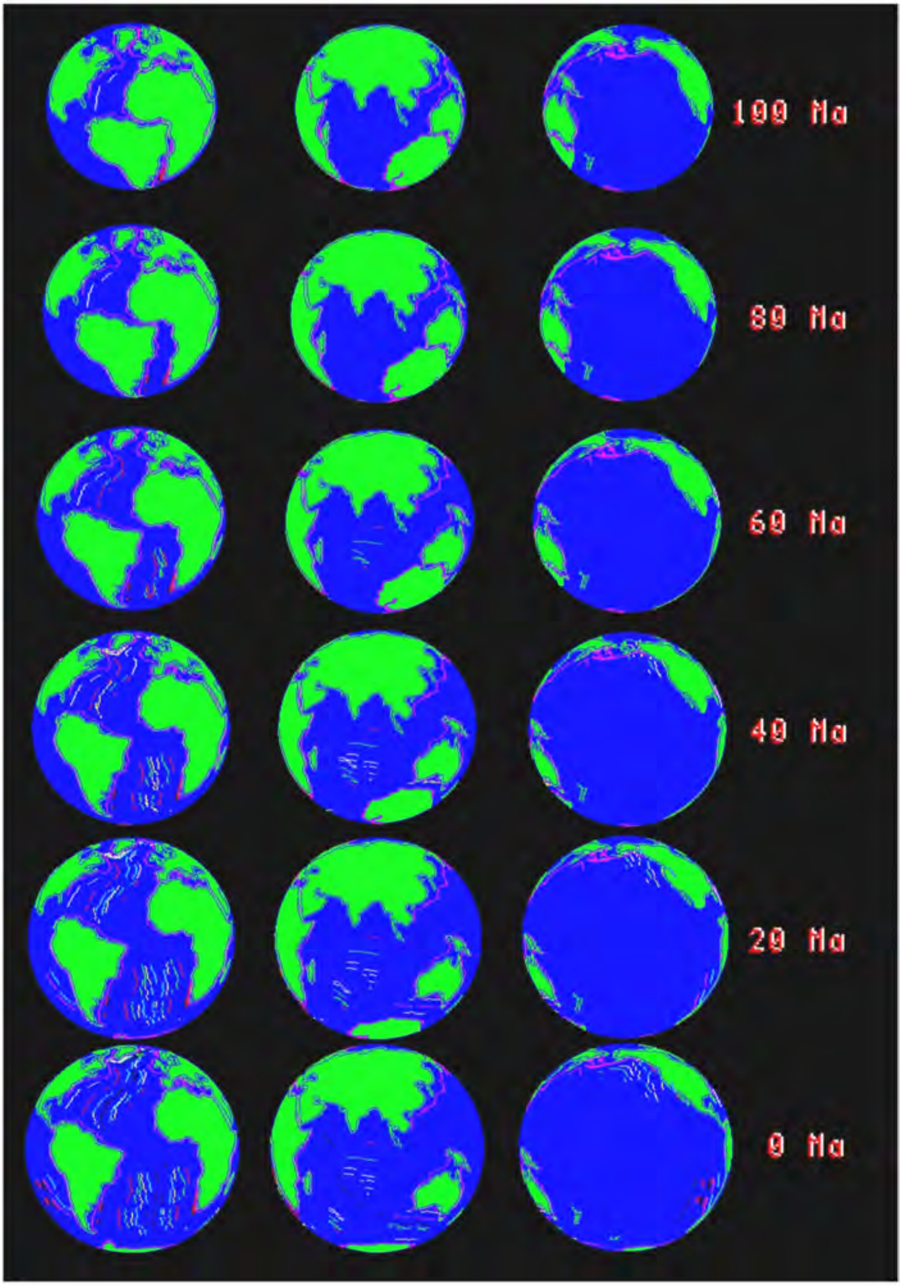

Fig. 8. A typical Expanding Earth reconstruction based on geological data.

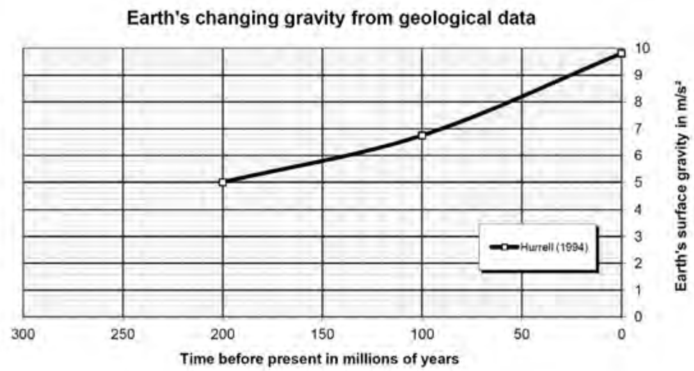

Fig. 9. Earth's changing gravity over time based on geological reconstructions of an Expanding Earth.

8. Implications for the expanding Earth

The magnetic recordings on the ocean floor have been mapped to give a detailed account of the age of the Earth's ocean floor. By removing the ocean floor that is known to be younger than a particular age, it is possible to reconstruct ancient Expanding Earth globes by rejoining the remaining ocean floors. A number of reconstructions have been produced by Hilgenberg (1933), Vogel (2003), Hurrell (1994, 2011), Luchert (2003), Maxlow (2005) and many others. Fig.8 shows a typical Expanding Earth reconstruction.

The estimates of ancient Earth's reduced gravity, indicated by the larger relative scale of ancient life, can be compared with estimates of gravity for Constant Mass and Increasing Mass Expanding Earth models. The force of the Earth's gravity is:

$$F = G \times M_1 \times M_2 / R^2, \quad (5)$$

where M_1 and M_2 are the masses of the two mutually attracting bodies, R is the distance separating them and G is Universal Constant of Gravity and the calculated force F is effectively the force of gravity.

For a Constant Mass Expanding Earth ancient gravity would be about four times the present value which does not agree with the results from ancient life. For an Increasing Mass Expanding Earth gravity would gradually increase over time as the Earth grew in diameter and mass so this agrees with the gravity results from ancient life.

This is a simplistic method of calculating the force of gravity since it assumes that the density of the ancient Earth is exactly the same as the present Earth. It is much more probable that as the ancient Earth grew larger in size and mass it would become denser as its core became more compact due to the increasing surface gravity (Hurrell 1994, 2003). This density increase can be estimated by plotting the known variation of gravity against the radius of other known celestial bodies, and a graph of changing gravity on the ancient Earth taking account of density variations in the Earth's core and mantle based on other celestial bodies is shown in Fig.9.

The Reduced Gravity Earth model agrees most closely with an Increasing Mass Expanding Earth model rather than a Constant Mass Expanding Earth model. Estimates of ancient life's gravity indicate that Earth Expansion is due to mass increase.

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