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A3_3 Megalodon't Go Down There

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Abstract

In this paper we investigated the validity of a megalodon surviving in the Mariana Trench as was shown in the 2018 movie 'The Meg'. By modelling the shark as both water and cartilage we have shown how the intense water pressure affects the shark's body. We deduced that it is very unlikely that a megalodon would be able to survive in such an extreme environment, with its bodies volume being compressed by a weighted average of 12%.

Introduction

In the movie 'The Meg' a megalodon is shown to have been living in the deepest part of the ocean, the Mariana Trench. In this paper we have estimated how much the pressure of the water will compress the shark and speculate on whether the megalodon could survive. We did this by using the fact that fish are approximately 80% water and assumed that this is also correct for the megalodon [1]. Since the shark is largely composed of water, which is one of the most highly incompressible materials in the shark's body, modeling the shark completely as water allowed us to estimate the effect the high water pressure would have on the shark's body. In addition we have also modeled the shark to be completely made out of cartilage so that it is possible to infer what would happen to the shark's skeleton.

Method

To do this first we calculated the pressure, P, of the seawater in the Mariana Trench by using equation (1), where air pressure is ignored because it is negligible.

$$P = \rho g h \tag{1}$$

We used the density of seawater, ρ, as 1000 kgm^{-3} [2], the acceleration due to gravity, g, as 9.8 ms^{-2} and the height, h, as the depth of the Mariana Trench, 11,000 m [3]. This gave a water pressure of 1.1×10^8 Pa.

Next we found the volume of the megalodon shark in normal pressure, which was achieved by taking the mass of a megalodon shark to be 30,000 kg [4]. Using the definition of density, with the density of water as 1000 kgm^{-3} [2], we estimated a volume of 30 m^3 since the shark is 80% water.

Finally, we calculated the volume change, dV, due to the compression on the shark by using equation (2) for both a shark made completely out of water and another completely of cartilage.

$$dV = \frac{V dP}{K} \tag{2}$$

To do this we used the relationship between the Young's modulus, E, and the bulk modulus, K. The relationship between K and E is seen in equation (3), where υ stands for the Poisson ratio, a measure of the deformation of a material under a force.

$$K = \frac{E}{3(1 - 2v)} \tag{3}$$

Discussion and Results

First we assumed the megalodon is completely made out of water. The bulk modulus of water is equal to 2.2×10^9 Pa [5]. Then we used equation (2) to calculate the change in volume that occurs due to the compression force of the high water pressure. Using the volume of the shark as 30 m^3, setting the change in pressure equal to the pressure at the bottom of the Mariana Trench, 1.1×10^8 Pa, and the bulk modulus constant as 2.2×10^9 Pa, the change in volume was calculated to be 1.5 m^3.

Next we assumed the megalodon was completely cartilage. In this case we needed to calculate a theoretical bulk modulus for the cartilage of a megalodon shark. To do this we took an average of the Young's modulus of a great white shark's jaw [6] giving a Young's modulus of 160×10^6 Pa. We then used equation (3), with a Poisson ratio for bone of 0.3 [7], to find a bulk modulus constant of 1.1×10^8 Pa. As great white sharks are a genetically close relative to the megalodon we assumed that they had a similar cartilage composition and therefore this bulk modulus is accurate. Repeating the calculation for the change in volume but instead using a bulk modulus of 1.1×10^8 Pa, we obtained a change in volume of 29 m^3.

The megalodon composed of water has a 5% change in the total volume whilst the the solid cartilage shark has a 96% change. From this we have shown that shark cartilage does not endure well against the intense water pressure. In this scenario it would be almost completely crushed despite being solid cartilage, we can therefore infer that the skeleton of a megalodon would suffer similarly. The water, however, resists pressure very well showing that water is highly incompressible. By taking a weighted average of the volume change as 80% water and 20% cartilage which is relatively accurate to a real shark an overall volume change of 12% is given. Its body would collapse under this pressure.

Conclusion

In conclusion it is almost certain that the shark would not be able to survive, this is because a loss in volume of 12% would pressure the internal organs, reduce the surface area of the shark's gills and as a result deprive the shark of oxygen. As the water pressure greatly affects the shark's cartilage, it would cause the shark's skeleton to compress and break, resulting in perforations and cuts inside of the shark's body that would lead to internal bleeding and most likely death. With all these negative factors afflicting the megalodon, the shark would almost certainly die in the Mariana Trench.

References

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