

## A1\_11 Can an Onix evolve into a Steelix?

T Glossop, S Jinks, R Hopton

*Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH.*

March 2, 2011

### Abstract

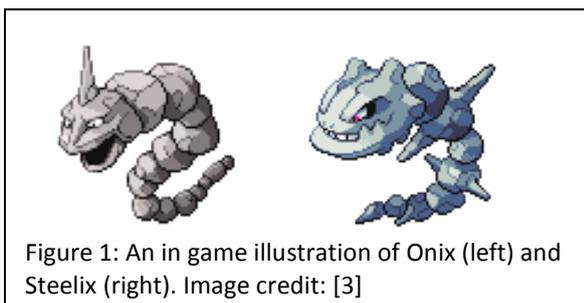
We review the method of the evolution of the Pokémon “Onix” into the Pokémon “Steelix” as stated by the existing games created by Nintendo, by modelling the transformation of carbon into diamond. We discuss two models: the first model being under high pressure converting a standard Onix into a Steelix, and the second where the Onix accretes mass and compresses to the correct size. Both models are found not to give the parameters specified in the games.

---

### Introduction

In the Pokémon series an Onix is said to be able to evolve into a Steelix by spending a lot of time at high pressures under the ground and converting its body to a diamond-like structure. [1]

Onix is a Pokémon that is 8.8 metres long and a mass of 210 kg [2] that for this article we will assume to be made of amorphous carbon (the most common form of pure carbon). Steelix is a Pokémon that is 9.2 m long and has a mass of 400 kg [1] that for this article we will assume to be made of diamond.



### Theory

Amorphous carbon can change into diamond under certain conditions. The pressure must be between 45 kilobar - 60 kilobar (4.5 GPa – 6 GPa) and occur at a temperature between 900°C and 1300°C (1173 K – 1573 K) [4]. These processes take up to billions of years to complete in reality [5].

The density of diamond is  $3520 \text{ kgm}^{-3}$  [6], the mean density of amorphous carbon is  $1950 \text{ kgm}^{-3}$  [7]. Therefore we will take the respective values for the density of Onix and Steelix,  $\rho_o$  and  $\rho_s$ , to be that of amorphous coal and diamond.

In order to find how much Onix is compressed so that its composition changes to that of diamond, we need to find the radii of Onix and Steelix and compare the two.

By modelling the two Pokémon as cylinders, of height  $h_o$  and  $h_s$ , with radius  $r_o$  and  $r_s$  for Onix and Steelix respectively, we can see that the volumes  $V_o$  and  $V_s$  are:

$$V_o = \pi r_o^2 h \quad , \quad V_s = \pi r_s^2 h \quad . \quad (1)$$

By rewriting the volume in terms of mass and density, and re-arranging (1) for  $r_o$  and  $r_s$  respectively we get that:

$$r_o = \sqrt{\frac{M_o}{\pi \rho_o h_o}} \quad , \quad r_s = \sqrt{\frac{M_s}{\pi \rho_s h_s}} \quad . \quad (2)$$

Solving for (2) numerically gives the radius of Onix,  $r_o$  to be 6.24 cm and the radius of Steelix,  $r_s$  to be 6.27 cm.

The Youngs modulus of amorphous carbon and diamond are 300 GPa [8] and 1220 GPa respectively [6].

Since the Youngs modulus is defined as:

$$Y = \frac{F}{\frac{\Delta l}{l}} = \frac{Pl}{\Delta l} , \quad (3)$$

where  $F$  and  $P$  are the force and pressure respectively exerted on the material,  $l$  is the original length of the material parallel to the force applied and  $\Delta l$  is the change in length due to the exerted pressure.

Since we are modelling the pressure from all directions (an isotropic pressure), we can re-arrange (3) for the change in length,  $\Delta l$ :

$$\Delta l = \frac{Pl}{Y} . \quad (4)$$

By substituting the correct values into (4) we get that Onix is crushed to a radius of 6.14 cm and a length of 8.67 m, which is a lot thinner and shorter than Steelix.

This means that under this assumption, an Onix could not evolve into a Steelix. However, we can assume that the original Onix in question consumes more rock of similar density so that it could be compressed to the correct dimensions of a Steelix.

Amorphous Carbon under these pressures will always be compressed by the same scale factor,  $S$ , which is defined as the change in the original length divided by the original length:

$$S \equiv \frac{\Delta l}{l} = \frac{P}{Y} = 0.015 . \quad (5)$$

If we divide the dimensions of Steelix by 1-5 then we get the dimensions that an Onix would have to grow to in order to be compressed to the correct sizes  $l_c$  and  $r_c$ . These give values of  $l_c = 9.34$  m and  $r_c = 6.37$  cm. This gives a new volume of  $0.119$  m<sup>3</sup> and

therefore a new mass of 232 kg, which is still far too light for it to be crushed into a Steelix.

## Conclusion

We have proved that an Onix cannot evolve into a Steelix in real life, and have the same characteristic mass and dimensions; even if it accretes more mass. Whilst the process has been heavily approximated (these include modelling the Pokémon as cylinders and assuming densities) the extra increase in mass of Onix that would satisfy the Steelix would make them far too large.

## References

- [1] Pokémon Gold version, Nintendo (1999)
- [2] Pokémon Red version, Nintendo (1996)
- [3][http://bulbapedia.bulbagarden.net/wiki/Steelix\\_%28Pok%C3%A9mon%29](http://bulbapedia.bulbagarden.net/wiki/Steelix_%28Pok%C3%A9mon%29), adapted from Pokémon Black version, Nintendo (2010) (2/3/11)
- [4]<http://www.hsamuel.co.uk/webstore/static/diamond-buyers-guide/diamond-information.do> (2/3/11)
- [5] Dan Hausel, E. E. W. Diamond deposits: origin, exploration, and history of discovery. 2002. Society for Mining, Metallurgy, and Exploration, Inc. (SME) Littleton USA
- [6]<http://www.chm.bris.ac.uk/motm/diamond/diamprop.htm> (2/3/11)
- [7]<http://invsee.asu.edu/nmodules/carbonmod/density.html> (2/3/11)
- [8] Schultrich, B., Scheibe, H.-J., Grandremy, G. and Schneider, D. (1994). *physica status solidi (a)*, 145: 385–392. doi: 10.1002/pssa.2211450219 (2/3/11)