

Charles Darwin in the Andes

Nelio Bizzo¹ and Luis Eduardo Maestrelli Bizzo²

University of São Paulo¹ at São Paulo and University of São Paulo at Ribeirão Preto², Brazil

Considering geological time as an important epistemological obstacle to the construction of ideas on biological evolution, a study was carried out on the so-called 'Darwin Papers'. The conclusion was that Charles Darwin's excursion in the Andes during March-April 1835 was a crucial step in this regard. An expedition was carried out in March-April 2002, in the exact same days of the year that Darwin had been there. The results of this expedition are described; these suggest a reappraisal of the traditional Darwin iconography and teaching strategies.

Keywords: Teaching evolution; Darwinism; Geological time.

Introduction

Teaching Biology relies, to a certain extent, on the understanding of the theory of evolution. Its centrality in Biology is widely recognised. Several papers have revealed that students face serious problems understanding key concepts of the evolutionary theory (Brumby, 1984; Engel-Clough and Wood-Robinson, 1985; Bishop and Anderson, 1990; Wood-Robinson, 1994; Bizzo, 1994). Several teaching programmes present evolutionary theory as a chain of inferences, leading students to consider science as a sort of rhetoric of conclusions. Other studies have focused on the way teachers should understand students' preconceptions, which are often based on religious beliefs, and how classroom teaching may be affected by familiarity with and dedication to the topic of evolution (Blackwell *et al.*, 2003).

We present here the results of a piece of research emphasising the context in which scientific ideas on evolution were discovered: in particular, the social and economic context in which they acquired their initial form, the social and personal issues which were involved and how the ideas about geological time were part of the context of discovery.

Considering geological time as an important epistemological obstacle to the construction of ideas on biological evolution, a study was carried out on the so-called 'Darwin Papers'. The conclusion was that Charles Darwin's excursion in the Andes in March-April 1835 was a crucial step in this regard. Other studies on Darwin's iconography, including the globally-known BBC series *Voyage of The Beagle* focused no attention on this crucial element.

An expedition was carried out in March-April 2002, in collaboration with a Brazilian educational TV channel (TV Cultura, SP) in order to find evidence that could become a part of teaching programs and enhance teachers' understanding of the context of the discovery of the evolutionary theory.

Although many biology textbooks give the impression that Charles Darwin was taught in a time when the age of the earth was believed to be 5000 years or so, there is plenty of evidence to indicate that learned societies at that time did not support that view. Not only the radical thinkers but also

learned clergymen, such as Adam Sedgwick, agreed that our planet was not the age many theologians stated, citing literal interpretations of the Bible. On the contrary, tens of thousands, hundreds of thousands or even millions of years were openly advocated. Nevertheless, the question remained open: what evidence was there to support such proposals?

Marine remains found far from the sea were appealing evidence awaiting exact explanation. Although many argued that they constituted evidence for the biblical deluge, few theologians, if any, believe nowadays that this can be the case. The case of marine remains found in mountains was studied in detail in the 18th century and even theologians agreed that they could not be taken as evidence of the deluge.

While from the 15th century, these marine remains had been taken as 'proof' of the Universal Deluge, by 1737 the abbot of Grezzana (Italy), Gian Giacomo Spada, had already written a strong argument against this tendency, addressing specifically the specimens found in the province of Verona (Caltran, 1974, Figure 1, opposite). On 27 January 1758, Lazzaro Spallanzani, who was not only a scientist but also a Catholic priest, addressed the question in his lecture *Dissertazione sopra i corpi marino-montani*, delivered at the Accademia degli Ipocondriaci di Reggio Emilia. Fossilised seashells were explained in terms of 'mineralisation'.

The crucial point was addressed when fossilised fish were discovered at Mount Bolca, in the area between the Veronese and the Vicentino, in northern Italy (Veneto), 800-970 metres above sea level. Spallanzani remarked that those fish species could not be found any longer in the region or even anywhere in the globe; therefore a recent event could not explain the great changes they witnessed. His conclusions were that these 'manino-montani' remains were clues of the geological activity of our planet, described as 'revolutions'. Mount Bolca and surrounding areas (Vetenanuova county) would have been an ocean floor (in fact a marine lagoon) in the distant past. In this and in following works, he studied the process of fossilisation in detail and concluded that fossilised timber was due to the action of water in past ages. How far away in the past? It remained an open question. (Spallanzani L, 1758).

The first collection of Bolca fossils, which was organised by Count Giovanbattista Gazola, was taken by Napoleon Bonaparte to Paris in his Italy campaign of 1796 and since then has been part of the Museum National D'Histoire Naturelle of Paris. Louis Agassiz would have his attention called to these fossils, as well as other prominent scientists of the 18th century, such as Charles Lyell (1797-1875), who in fact visited Bolca in person. The question of geological time was truly an issue when Charles Darwin was on board the *Beagle* in his voyage of circumnavigation.

In his well-known address in Trinity College Chapel to the Master, Fellows and students in the annual service of 17 December 1832, Rev Adam Sedgwick (1785-1873) stated:

"The Geologist tells us, by the clearest interpretation of the phenomena which his labours have brought to light, that our globe has been subject to vast physical revolutions. He counts his time not by celestial cycles, but by an index he has found in the solid framework of the globe itself. He sees a long succession of monuments each of which may have required a thousand ages for its elaboration. He arranges them in chronological order; observes marks of skill and wisdom on them, and finds within them the tombs of the ancient inhabitants of the earth." (Sedgwick, 1833, emphasis added).

Sedgwick was a recognised geologist; although very popular, his lectures on the subject were not part of the curriculum in Cambridge. However, eighteen months before his address in Trinity College Chapel, when Hamilton was launching his famous assault on the old English universities and their old-fashioned curricula, Adam Sedgwick was hiking in Wales with the young Charles Darwin. In his field excursion in the 1831 summer he certainly showed the marks of the "vast physical revolutions" earth had experienced, how impossible it was to count down their timing by "celestial cycles" and how each one of these changes "required a thousand ages for its elaboration". It is known that Sedgwick asked Darwin to look for traces of red sandstone in the Clwyd Valley. Failing to find them, there was no other conclusion than erosion must have worked for "thousands of ages".

Sedgwick, as well as Charles Lyell, could not accept 'biological transmutation' including an alternative origin for mankind other than the divine. Humans would have been on earth for some few thousand years and, Lyell argued, in his classic *Principles of Geology*, that the comparison of Egyptian mummies with 'modern' man revealed no differences. This evidence and the importance attributed to it show clearly how geological time was difficult to conceive; geologists who were intensively working on the question could hardly admit that 'thousand of ages' would mean thousands of million years. As soon as 1863, Lyell published his famous *The Geological Evidence of the antiquity of Man*, where he presents a number of evidences of geological time, stating that this had a direct impact in Darwin's evolutionary theory (Lyell, 2004). A description of the geology of that time is given in Rudwick, 1985.

Teaching evolution today

There have been a number of papers showing how students fail to understand biological evolution. Even medical students show clear evidence of misunderstandings of basic concepts (Brumby, 1984). Other papers show the same picture in several countries and different student ages (Bishop *et al*, 1990; Wood-Robinson, 1994; Bizzo, 1994; Moore *et al*, 2002).

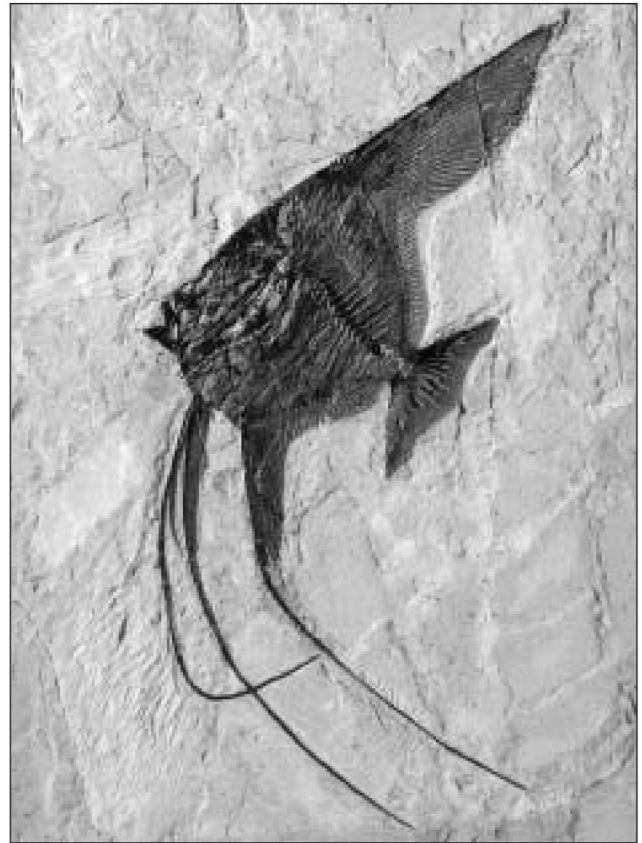


Figure 1.

As part of our theoretical thrust, the causes of failure of the teaching and learning have to be looked for not only in the teachers' skills or students' abilities but also in the knowledge itself. From the epistemological point of view, the ways in which a certain concept was constructed can throw some light in the way learners can approach this knowledge nowadays. The relationships between history and philosophy of science and science teaching has been a growing field of research and the literature produced in the area witnesses this growth.

The Darwin Papers

The so-called Darwin Papers were studied in order to answer the following question: when did Charles Darwin unlock the door of geological time, moving ahead of what was acceptable in learned societies in his time?

It was remarkable to discover that the question of geological time was one of Darwin's main research objectives during his voyage on the *Beagle*. Soon after arriving back to England, he met Charles Lyell and exchanged views about the proof he had found. He had particularly enjoyed his field excursions to the Andes, where he found concrete proof of how ancient our earth was. They met at Charles Lyell's house on 2 January 1837 and, two days later, he read in the Proceedings of the Geological Society of London his paper *Observations of proof of recent elevation on the coast of Chile, made during the survey from His Majesty's Ship Beagle, commanded by Capt. Fitzroy RN* (Darwin, 1837). In fact, what he had found in his field excursion of March-April 1835 was remarkable, as we can find in many sources, such as his published letters and his own account which was put forward in his *Voyage of the Beagle*, first published in 1839.

However, even before returning home, he was so sure of how relevant his findings were that he had sent a memoir to

be read in England (Darwin, 1835). In this paper, the petrified forest of Villavicencio is mentioned as a key finding. The petrified forest of Villavicencio was mentioned in many letters and appeared in his *Voyage of the Beagle* as an example of the extraordinary facts which were documented in his field excursions. He wrote:

"In the central part of the range, at an elevation of about seven thousand feet, I observed on a bare slope some snow-white projecting columns. These were petrified trees, eleven being silicified, and from thirty to forty converted into coarsely-crystallized white calcareous spar. They were abruptly broken off, the upright stumps projecting a few feet above the ground. The trunks measured from three to five feet each in circumference."

Soon after visiting this spot in the Andes, Darwin wrote an important letter to John Henslow (18 April 1835), in which one can read:

"In an escarpment of compact greenish sandstone I found a small wood of petrified trees in a vertical position (...). Eleven are perfectly silicified, and resemble the dicotyledonous wood which I found at Chiloe and Concepcion: the others, thirty to thirty-four in number, I only know to be trees from the analogy of form and position; they consist of snow-white columns (like Lot's wife) of coarsely crystallized carbonate of lime. The largest shaft is seven feet. They are all close together, within one hundred yards, and about the same level; nowhere else could I find any. It cannot be doubted that the layers of fine sandstone have quietly been deposited between clumps of trees, which were fixed by their roots. (...) I am quite afraid of the only conclusion which I can draw from this fact, namely, that there must have been a depression in the surface of the land to that amount."

In these lines there are clear implications of the question of geological time. To Henslow he wrote "I am quite afraid of the only conclusion" as he was confirming that only "a thousand ages" would allow enough time to explain all the evidence which was gathered at that time.

Research results

It was surprising to discover that the question of geological time was not addressed in basic education in many countries. Previous studies have showed that students are aware of how old the earth is: however, they do not apply their knowledge to concrete situations. High school students did not differentiate between a two million year and a 200 million year time span, two radically different time periods (Renner, Brumby and Shepherd, 1981).

From the historiography point of view, little attention is given to the fact that Charles Darwin constructed his intellectual theory first on geological grounds. Soon his authority was reflected by his election to a position of power, as secretary of the Geological Society of London. It is necessary to point out the importance of geology to the British economy at that time, Britain being the first world exporter of mineral coal. Carboniferous strata had a similar importance then to that of oil fields nowadays.

It was even more surprising to discover that no major attention has been given to Darwin's field excursion of March-April 1835 in popular literature. Popular works, for instance, Huxley and Kettlewell's Darwin's biography (*Charles Darwin and His World*, 1965), hardly mentions the excursion. In fact, the only mention is about the possibility of Darwin's



Figures 2 (above) and 3 (below). Seashells found in the Andes. Figure 3 shows details of a large rock, where hundreds of seashells "almost blended together" can be seen.



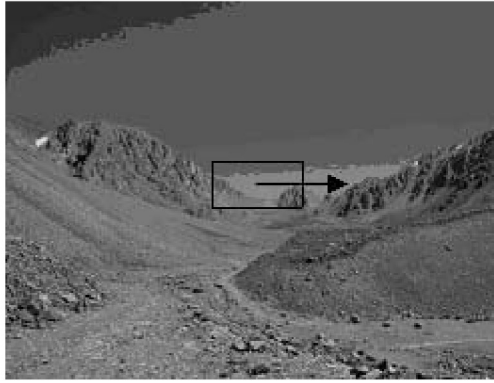
contracting Chagas' Disease, as he had been severely bitten by the 'pampas bug', locally known as 'benchuga' (*Triatoma infestans*). The traditional Darwin iconography includes neither images of the petrified forest of the Andes nor the fossilised seashells found at great altitudes. The BBC documentary *The Voyage of the Beagle*, although supported by an acute and precise historiography consultancy, does not contain any images or discussion about the remarkable finding of Villavicencio.

Darwin scholars used to believe that this petrified forest does not exist anymore. In fact, Richard Keynes (2003) states that only the fossil seashells can be found in the original place, which would have been reshaped to build the modern road between Santiago and Mendoza. Engineers and souvenir hunters would have destroyed all fossilised trunks.

In order to remedy this gap in the iconographic record, three field excursions were carried out in this region in the period 1996-2002. The main results are shown below, in terms of images and brief descriptions of the findings and transcriptions from Charles Darwin's *Voyage of the Beagle* (1839).

As he began the crossing of the Andes, in mid-March 1835, Charles Darwin found a number of seashells. This was not exactly surprising, as he had investigated many former seabeds before reaching the Andes. The importance of these seashells was paramount, as it could also reveal how deep they could possibly have lived. He wrote:

"In these upper beds shells are tolerably frequent; and they belong to about the period of the lower chalk of Europe. It is an old story, but not the less wonderful, to hear of shells



Figures 4 (above left) and 5 (above right). The Portillo Pass in Argentina (eastern side). The route was entirely abandoned around 1890, when a railway was inaugurated between Mendoza and Santiago. Figure 5 shows detail.



Figures 6 (above left) and 7 (above right). One of the authors (Luís Eduardo) standing exactly on the 'Portillo' on a clear day. Figure 7 shows the view from that spot.

which were once crawling on the bottom of the sea, now standing nearly 14,000 feet above its level."

The highest point Darwin reached in his field excursion (in fact, in his whole life!) was the Portillo Pass, 4250 metres (13,943 ft) above sea level. (Darwin's estimate was 14,305 ft). He was not very lucky in his trip at that time, as he wrote:

"When nearly on the crest of the Portillo, we were enveloped in a falling cloud of minute frozen spicula. This was very unfortunate, as it continued the whole day, and quite intercepted our view. The pass takes its name of Portillo, from a narrow cleft or doorway on the highest ridge, through which

the road passes."

In our trip we were quite lucky, as we reached the Portillo on a very clear day and the view was magnificent. Darwin describes what is known locally as the 'vento blanco' (white wind) which our guide said occurred frequently here: it is a sort of snow and strong winds. In the night, we saw the clouds clear away and a full moon brought a quite magical effect. In fact, Darwin's description of the same day, some 167 years ago, was of much colder weather. For instance, he reported having seen a frozen horse just before the Portillo. In fact, he did not notice a 'mountain' of frozen cows which

Figures 8 and 9. The 'caracoles', the road of the tedious ascent up to Uspallata (left) and the gold mines (right) near the petrified forest.





Figures 10 (above) and 11 (below). On the bare slope of sandstone (left), and what is left of one of the silicified trunks near the gold mines.



can still be seen on the western side of the Portillo. Since the 18th century the road has been used by the cowboys to take cattle to the port of Valparaiso. At the Portillo, the highest point, the cattle were tired and ‘punado’ (the local name for altitude sickness), and many fell down in the abyss of the western side. They rest there, even today, forming a frozen mountain of cattle.

After leaving Mendoza, Darwin arrived at Villavicencio, a place which would hardly deserve to be called villa, as it was a solitary hovel. Darwin mentions, on his record for 30 March 1835, that he stayed there and at some “neighbouring mines during the two succeeding days”. That is unlikely as the mines and petrified forest, which he then found, were 20 km away from this place. The road, the ‘caracoles’ (Figure 8) is a winding road; 10 mules would take a whole day to arrive at the height of 2600m. In fact, we found ruins of another old house at that point, a place not mentioned in his diary and long known as ‘hornillos’. It is very likely that Darwin, Mariano Gonzales (his guide) and the ‘arriero’ stopped there, where there was certainly pasture for the mules and water for all. The following day (1 April) Darwin probably left and arrived at the gold mines, where he explored and then found the petrified woods.

Near the gold mines, which were in the middle of volcanic rock, Darwin observed some snow-white projecting columns on a bare slope of sandstone. These were petrified trees, eleven being silicified, and from 30 to 40 converted into coarsely-crystallised white calcareous spar. There was no doubt that these trees could never have grown on that spot, a real desert.



Figures 12 (above) and 13 (below). Trees converted into coarsely-crystallised white calcareous spar.



Darwin had seen trees only on the Chilean side of the mountains, near sea level. He had no doubt that he was facing clear evidence of the “great geological revolutions” that Sedgwick used to speak about. Furthermore, as he was 7,000 feet above sea level, there was some chance that he was in fact facing a real geological clock.

In addition, there was no possibility that these petrified trees could have been transported to that spot floating in water, as they were perfectly parallel and some of them were in the horizontal position, as if they had fallen down on the ground.

The combination of the findings of that excursion led Darwin to conclude that the forest and the sea-floor, which was almost 1000 metres above them, would tell a story of a very ancient planet. Trees, like those petrified ones would have lived millions of years ago. Other living beings could possibly be much older. Darwin wrote:

“It required little geological practice to interpret the marvelous story which this scene at once unfolded; though I confess I was at first so much astonished that I could scarcely believe the plainest evidence. I saw the spot where a cluster of fine trees once waved their branches on the shores of the Atlantic, when that ocean (now driven back 700 miles) came to the foot of the Andes. I saw that they had sprung from a volcanic soil which had been raised above the level of the sea, and

that subsequently this dry land, with its upright trees, had been let down into the depths of the ocean. (...) Vast, and scarcely comprehensible as such changes must ever appear, yet they have all occurred within a period, recent when compared with the history of the Cordillera; and the Cordillera itself is absolutely modern as compared with many of the fossiliferous strata of Europe and America."

Educational implications

We believe that a deep reappraisal of Darwin's trans-andean excursion may be important for educational purposes. As we have showed elsewhere (Bizzo, 2002), clear proof of the uprise of the Andes was a crucial step in Darwin's conception of geological time. Teachers should be well aware of how difficult it is to conceive biological evolution without a clear understanding of geological time. Mentioning 'thousands of millions' to students nowadays may be as vague as was 'thousand ages' in Sedgwick's own words. For Darwin, it was a crucial step to calculate how long a pretified forest would have taken to rise 3,000 metres at a rate of one inch a century, let alone the petrification itself. Our students could well attempt similar tasks before a regular programme on biological evolution.

Acknowledgements

This research has a Grant from the Brazilian National Council of Research - CNPq, (proc. 300786/93 and PET). We are grateful to David Burton, TV Cultura (SP), Monica Teixeira, Valeska Dios, Marcelo Jordão and Neli Rachel.

References

- Bishop B A and Anderson C W (1990) Student conceptions of natural selection and its role in evolution. *Journal of Research in Science Teaching*, **27**: 415-427.
- Bizzo N M V (1992) Darwin on Man in the *Origin of Species*: Further Factors Considered. *Journal of the History of Biology*, **25**(1): 137-147.
- Bizzo N M V (1994) From Down House Landlord to Brazilian Highschool Students: What has happened to evolutionary knowledge on the way? *Journal of Research in Science Teaching*, **31**: 537-556.
- Bizzo N M V (2002) *Darwin: do Telhado das Américas à Teoria da Evolução*. S.Paulo, Ed. Odyseus.
- Blackwell W H, Powell M J and Dukes G H (2003) The Problem of Student Acceptance of Evolution. *Journal of Biological Education* **37**(2): 58-65
- Brumby M (1984) Misconceptions about the concept of natural selection. *Science Education* **68**: 493-503.
- Caltran T (1974) *Bolca, laguna petrificada*. Verona, Ed. Corev.
- Darwin C R (1835) "Geological Notes Made During a Survey of the East and West Coasts of South America, in the Years 1832, 1833,

- 1834, and 1835, with an Account of a Transverse Section of the Cordilleras of the Andes Between Valparaiso and Mendoza. *Proceedings of the Geological Society of London*, v. 2, no. 42, p. 210-212.
- Darwin C R (1837) Observations of proofs of recent elevation on the coast of Chile, made during the survey of His Majesty's Ship Beagle, commanded by Capt. Fitzroy, R.N. *Proceedings of the Geological Society of London*, **2**(48): 446-449.
- Darwin C R (1839) *Journal of Researches into the Geology and Natural History of the Various Countries Visited by HMS Beagle, under the Command of Captain Fitzroy RN. From 1832 to 1836* [1st ed.]. London: Henry Colburn, xiv + 615 p.
- Darwin C R (1840) On the connection of certain volcanic phenomena in South America; and on the formation of mountain chains and volcanoes, as the effect of the same power by which continents are elevated. *Proceedings of the Geological Society of London*, **(2)5**(3); pp 601-631
- Dawson F G A *Primeira Crise da Dívida Latino-Americana*. S.Paulo, Studio 34.
- Engel-Clough E and Wood-Robinson C (1985) Children's understanding of inheritance. *Journal of Biological Education* **19**: 304-310.
- Huxley and Kettlewell (1965) *Charles Darwin and His World*. London, Book Club Associates.
- Keynes, R D (2003) *Fossils, Fences and Fueguians*. Harper Collins (London).
- Lewis J, Leach J and Wood-Robinson C (2000) What's in a cell? – Young people's understanding of the genetic relationship between cells within an individual. *Journal of Biological Education* **34**(3): 129-134.
- Lyell C (2004) *The Geological Evidence of the antiquity of Man*. New York. Dover Publications.
- Moore R, Mitchell G, Bally R, Inglis M, Day J and Jacobs D (2002) Undergraduates' understanding of evolution: ascriptions of agency as a problem for student learning. *Journal of Biological Education* **36**(2): 65-71.
- Renner J W, Brumby M and Shepherd D L (1981) Why are there no dinosaurs in Oklahoma? *The Science Teacher*. December, 22-24.
- Rudwick M J S (1985) *The Great Devonian Controversy: the shaping of scientific knowledge among Gentlemanly specialists*. University of Chicago Press.
- Sedgwick A (1833) *A Discourse on the Studies of the University*. (reprint). Leicester University Press (1969).
- Spallanzani L (1758) *Dissertazione sopra i corpi marino-montani*. Accademia degli Ipocondriaci di Reggio Emilia. Edizione Nazionale delle Opere di Lazzaro Spallanzani, (1994).
- Wood-Robinson C (1994) Young people's ideas about inheritance and evolution. *Studies in Science Education* **24**: 29-47.

Nelio Bizzo (corresponding author) is a full Professor of Science Education at the School of Education, University of São Paulo, Brazil. Email: bizzo@usp.br Luis Eduardo Maestrelli Bizzo is a graduate student of the University of São Paulo at Ribeirão Preto, where he is researching the evolutionary biology of Diptera.

BioEd e-newsletter

Looking for exciting new biology or science teaching resources? Want summary information on some of the latest Biology education topics? Want to go on a course for biology or science teachers to further enhance your professional development? Looking for further funding for your school? Looking for a teacher award or prize giving scheme? Looking for an exciting biology or science outdoor activity?

The Institute of Biology's BioEd electronic newsletter offers information on all of the above and it is FREE!!

To get BioEd News, direct to your inbox four times a year, simply email
Olga Zolle, Education Officer at o.zolle@iob.org



www.iob.org

The Institute of Biology is a Registered Charity, No. 277981

