

## An investigation on the development of pupils' ideas about the rock formation

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### ABSTRACT

*The purpose of our research is to address the development of the concept of rock formation in the reasoning of children, by collecting the pupils' ideas about a sedimentary rock bearing fossil molluscs. Here we present the data collected for 40 seven-year-old children, through individual, semi-structured interviews. Children's responses were categorised and interpreted. The results of this investigation indicate a transition from the diversified explanations we previously collected for preschoolers, including anthropomorphic or other fantastic elements, to the explanations based on human action or natural processes, given by seven-year-old children. Some of the scenarios envisaged by the pupils reveal the idea that the natural environment has changed in time.*

### KEYWORDS

*Earth sciences concepts, nursery school, primary school, sedimentary rock, geological time*

### RÉSUMÉ

*Le but de notre recherche est de comprendre l'évolution des concepts inhérentes à la genèse des roches dans le raisonnement des enfants, de l'école maternelle à l'école primaire, jusqu'à le collège. L'approche méthodologique consiste à collecter des descriptions orales et des dessins d'une roche sédimentaire avec des fossiles. Nous présentons ici les données collectées pour 26 enfants de 7 ans, à travers des entretiens individuels semi-structurés faits par l'enseignant. Nous faisons après une comparaison avec les descriptions orales et les dessins recueillis*

*précédemment pour enfants de 5 ans. Les enfants constatent la dissonance de la présence des coquilles, qu'ils associent à la mer, dans une roche qui vient de la montagne, et ils sont demandés de donner une raison pour cette discordance. Nos résultats, bien que ce soit une étude encore à la petite-échelle, montrent la transition d'une diversification des explications proposées des enfants de 5 ans, qui s'appellent à des éléments fantastique ou naturels, à des explications plus rationnelles des enfants de 7 ans. Certaines des explications révèlent l'idée que l'environnement naturel se modifie dans le temps.*

### **MOTS-CLÉS**

*Concepts de sciences de la Terre, école maternelle, école primaire, roche sédimentaire, temps géologique*

### **INTRODUCTION**

This paper illustrates the results of a research about the children's ideas on the appearance and the origin of the rocks. In particular, we explored how pupils describe a sedimentary rock, because the sedimentary processes could be easier to be envisaged with respect to magmatic or metamorphic ones.

The first step of the research was described elsewhere (Pieraccioni, Gioncada & Bonaccorsi, 2018); it was addressed to 40 five-year-old children to investigate how they described the sedimentary rock and tried to explain the occurrence in it of several well-visible shells (Figure 1). Each preschooler described and drew the rock, both before and after a learning sequence about the erosion and transport processes. The learning sequence was adapted to the age of children through the narration of the story of a character, initially a boulder then pebble and finally grain of sand, who travels from the mountain to the seaside. The results of those interviews carried out before the learning sequence are here compared with the results of the second step of the research, as described hereafter. It was addressed to seven-year-old children of the second class of primary school; in this second step the children did not perform any learning sequence about the rocks after the interviews.

**FIGURE 1**



*The rock examined by the children*

## THEORETICAL FRAMEWORK

The daily experience of children is connected with the reality but also with the pretend play, the imagination, the fiction, the daydreams (Piaget, 1964/1967). Children's concepts about geologic phenomena arise from their daily experience (Libarkin & Schneps, 2012), but we can expect that their ideas on rocks may be connected also with freaks and fantasies closer to their imaginations (Piaget, 1929). On the other hand, fantasies are produced not only by children but also by adults. For example, “freaks and fantasies of an industrious Earth and of a nature that relaxes” (Godard, 2017) were the ideas of some natural historians of ‘600 that “denied the organic origin of fossils, and attributed them to spontaneous generation in the ground” (Godard, 2017). The scientific thought of the Mankind developed in time; equally, it would be interesting to observe if also children’s ideas have a similar development. In fact, “although early childhood children have not yet developed their scientific thinking and understanding they do have initial representations of the concepts and the phenomena of physical world and they are also able to articulate composed reasoning in order to express their ideas about the natural environment” (Georgantopoulou, Fragkiadaki & Ravanis, 2016).

It was noted by Henriques (2002) that few researches existed in children's ideas related to geoscience; however, some studies have been published, about the way pupils and students describe the rocks and their origin. In the following we will briefly recall only the results of studies which address more specifically to children in the primary schools.

The early ideas about the rock formation were firstly investigated by Piaget (1929), who found that children up to seven- or eight-year-old used artificialism to explain the origin of rocks. In many of their answers, it appeared that rocks were man-made, obtained through the sticking of small grains and pebbles, or by pressing earth and soil. Other answers seemed to point to a more animistic view: the rocks grew up from seeds, they were living beings, even if their origin depended always on the human action (Piaget, 1929). According to Piaget, before reaching a naturalistic point of view, children proceed through an intermediate stage, in which some natural elements, such as water, play a significant role in the formation of rocks, but do not substitute completely the artificial explanation.

A deep study of the children’ ideas about soil, rocks and weather was performed by Russell, Bell, Longden & McGuigan (1993) for 34 pupils ranging from 5 to 11 years old. With regard to rocks, these authors asked to pupils to describe different samples of rocks and where they thought rocks might be found. Moreover, the authors investigated also the children’ ideas about both the possible changes of rocks in time and how long rocks have existed. They found that the main changes suggested by children were the breaking into smaller fragments and, in minor extent, the particle aggregation or 'bits sticking together'. The human intervention was the most claimed as agent of these transformation (Russell et al., 1993).

Ford (2005) examined the written description of rocks by 34 third graders, and emphasised the differences between the criteria selected by pupils and geologists in describing the rock samples, as well as in classifying the different materials (Happs, 1982). She put in evidence that the mere observation and description of the rock properties might actually hinder the discipline content, and the actual meanings that the rocks have for the geological science. To overcome this issue, the author suggested to link the observed properties of rocks to their formation origins, in order to contextualize the instructional exercise and to direct the descriptions to a more significant geological understanding. According to Blake (2004), it is important to introduce year 5 and year 6 children to the concept of the rock cycle, by using functional analogies. That allows them a better organization of their knowledge, and to recognize

that rocks are the products of particular natural processes (Blake, 2004). The same author (Blake, 2005) surveyed 115 children (aged 7-11) as regards structure, processes and materials of the Earth and, among them, interviewed 20 children about their ideas on the origin of rocks. It resulted that the rock formation interviews presented the highest percentage of “level 0” answers (when children did not respond; Blake, 2005), so indirectly confirming the complexity of this matter.

In the context of this topic, as well as of other topics in Earth science, it is interesting to verify the possibility that children are able to formulate a “retroductive reasoning”, according to the definition of Libarkin & Schneps (2012), i.e. the application of their experience of the present to explain a past event. Libarkin & Schneps (2012) interviewed 21 children of all the classes of primary school about various Earth-related topics (rock formation, soil, Earth’s interior, volcanoes, plate tectonics) to verify the children ability to use their present experiences to infer an explanation for the past phenomena. They concluded that “young children are capable of making this type of inference about the past from modern evidence”; the most evident given examples of that conclusion came from few children of 3<sup>th</sup>, 4<sup>th</sup> and 5<sup>th</sup> classes (Libarkin & Schneps, 2012).

The investigation of the children’s ideas about the rocks and their origin is linked to studies more focused on the occurrence of possible alternative conceptions about the same topic. Several studies were carried out to check the occurrence in pupils and students of alternative concepts about the rock formation (Blake, 2005; Cheek, 2010; Dal, 2007, 2009; Dove, 1998; King, 2008). For example, pupils of all ages perceive rock as a dull, heavy, large, dark material (Dove, 1998). Russell et al. (1993) report that young children consider stone, pebbles, sand and rock as separate entities, rather than materials sharing attributes of a common parent material. In general, both children and adults have problems in distinguishing minerals and rocks (Gosselin & Macklem-Hurst, 2002). Alternative concepts such as pebbles that grow, human involvement in rock formation, and sedimentary rocks forming as puddles dry up, emerge in preservice teachers that have completed a college-level course in Earth science (Kusnick, 2002).

### ***The research questions***

Almost all the previously cited papers considered a limited number of pupils, mainly within an Anglo-Saxon education system. We thought that it would be of some interest to examine a different education framework (the Italian mandatory schools, which include students from six to 16-year-old, and the kindergarten school for five-year-old children) and to perform a cross-sectional study sampling homogeneous groups of children of different ages. This paper reports the description of the second step of this project (with seven-year-old children), whereas the first step is published elsewhere (Pieraccioni, Gioncada & Bonaccorsi, 2018) and the successive steps are yet in progress.

The purpose of this research is to recognize the first concepts associated to the rock formation in the reasoning of children, and to follow their possible modifications. In particular, we are interested in exploring and, if possible, understanding the children’s lines of reasoning about a natural process involving time beyond human scale, such as sedimentary rock formation. The research questions are:

1. How seven-years-old children describe a sedimentary rock with fossil shells?
2. Do they use words referring to transformations of the natural environment in time?

## METHODOLOGICAL FRAMEWORK

### *The overview of the study*

This paper describes the results of semi-structured interviews, carried out with seven-years-old children, about the description and the origin of a big piece of sedimentary rock, bearing large fossil shells of molluscs (Figure 1). The respondents were 40 pupils (21 females and 19 males) attending the second class of three different primary schools in the Massa area, Tuscany, Central Italy. All the three primary schools were situated in a urban area of low-medium socio-economic status. By a geographic viewpoint, Massa is placed in a small strip of land enclosed between the foot of the Apuan Alps and the Ligurian Sea. This area is not strongly anthropized and people can still enjoy the contact with the nature.

The three classes were chosen because the teachers volunteered to facilitate our study. The three sets of data will be named VO (16 children), SL (10 children) and OR (14 children) in the following. The children were familiar with educational interactions, since the interviews were carried out in the last period of the school year; their overall level as pupils was low-medium, according to the teacher evaluations. The topic of the rocks formation has not been discussed in the three classes before the interviews.

We chose not to perform directly the conversations with the children, in order to favour a didactic environment as normal as possible; the teachers of the classes agreed to help us in collecting the comments and ideas of the children, following a shared protocol. The answers were tape-recorded by the teachers in a separate, quiet place, to not disturb the child.

### *The interview protocol*

Before starting the interviews, the teacher assigns a code to each child to safeguard the identity of the children during data processing by the researchers. During the interviews, she asks the pupils to help her in describing the rock which a friend of hers collected in the mountain: "Please, look at this piece of rock that my friend found in the mountain. He asked me to put forward some guesses about how it is made so I thought to bring it at school to be helped by you. What do you see in this rock, collected in the mountain?"

The protocol highlights that it is important to use the words *rock*, *stone*, *pebble*, etc. to correctly suggest that it is a natural, not man-made object; moreover, the interviewer should clearly specify that the place of discovery is a *mountain*. After the children indicate the occurrence of shells in the rock, the teacher invites them to guess a possible explanation: "In your opinion, given that the rock was found in the mountain, why are there shells in this rock, if shells are usually at the sea?". At the end of the conversation, the teacher asks the pupil to draw the rock. Apart from the two questions reported above, common to all the interviews as required by the investigation protocol, the teachers had different interactions with the pupils during the conversations, depending on their attitude. In particular, VO and OR teachers restricted themselves to the questions of the protocol, while the SL teacher talked with the pupils, soliciting their answer also by rearranging the question formulation. However, they probably behaved accordingly to their daily habits with the children. As regards the drawings, while the VO and OR teachers asked to draw the examined rock, the SL teacher asked pupils to draw what they had envisaged. Anyway, we decided not to discuss here the topic of the children's drawings, putting off that to a successive paper.



### ***The overview of the analytic procedure***

The tape-recorded interviews of the children were transcribed and analysed to look for common features and for the emergence of ideas about the transformations of the natural environment in time. Following the procedure we had used in the previous study with preschoolers (Pieraccioni, Gioncada & Bonaccorsi, 2018), we filled out a form to have an overview and a better summarizing picture of the children ideas. The conversations were separately analysed by the four authors and the detected features were discussed together.

The identified categories were five: 1) no explanation; 2) human intervention (e.g. *“somebody took the rock from the sea and brought it up to the mountain”*); 3) a lake or river occur near the discovery place (e.g. *“sometimes in mountain there are lakes and therefore the shells come from a lake”*); 4) changes occurred in time (e.g. *“many years ago there was the sea”*); 5) the shells actually are stones (e.g. *“it seems a shell, but it isn’t”*).

## **RESULTS**

The analysis of the data collected shows that the shells in the rock are immediately noted by all the 40 children. Several children note other geological elements of the rock: little pebbles and sand are mentioned by 22/40.

The pupils easily associate the clam-shells to the seaside. When the teacher states that the rock was found in the mountain, all the pupils seem aware of the contradiction between the two statements. One of the pupils notes that *“the sand, also, is at the sea”*. This pupil faces the cognitive dissonance by asking for a confirmation (*“did your friend really find it in the mountain?”*), demonstrating to point to a simple and straightforward explanation: the adult made a mistake, clam-shells and sand are at the sea and not in the mountain.

As regards the problem of the occurrence of shells in a rock, more than half of the children (22/40 children) do not provide any explanation for that (Table 1). It is interesting to note that, among them, only two children belong to the SL class. It may depend on the fact that, whereas the teachers of the VO and OR classes encouraged the pupils to answer but accepted the answer *“I don’t know...”* without replying, the teacher of the SL class invited repeatedly pupils to guess an answer.

**TABLE 1**

Children’s answers analysed according to the five categories individuated

<b>Category</b>	<b>VO</b>	<b>SL</b>	<b>OR</b>	<b>total</b>
1. the pupil does not provide any explanation	12	2	8	22
2. the pupil suggests human intervention	3	3	2	8
3. the pupil suggests that a lake or river is present in the mountain today	0	4	1	5
4. the pupil suggests that changes occurred in time (once there was the sea or a lake in the mountain)	1	1	1	3
5. the pupil suggests that the shells actually are stones	0	0	2	2

The rest of the interviewed pupils (about half) gives four categories of explanations: 8/40 propose human intervention to carry the shells or the rock itself from the seaside to the mountain (*“one person may have brought them from the sea, they may have fallen”*, *“by the car”*, *“some boys may have played with the shells, they may have thrown them”*); 5/40 suggest the presence of a lake or

a little river in the mountain, making an equivalence between the availability of water and the possibility to have shells, or suggest the proximity of the mountain to the sea (“*they found it at a lake*”, “*maybe there is the sea behind the mountain*”); three pupils suggest that once in the past there was a lake or a sea where the rock has been found (“*there was a lake, then it has disappeared*”, “*many years ago there was the sea, the mountain was made of sand*”, “*in the time of years, the sea dried out*”). These three last answers introduce the possibility that the environment was different in the past, to reconcile the contradiction of shells in a mountain rock. The time is undefined (“*there was.... then....*”, “*many years ago*”, “*in the time of years...*”), but these children seem to consider the possibility that the Earth surface is not static or immutable to put in agreement discordant information. The last category includes two children who, after having seen and recognized the shells in the rock, solved the dilemma of the seaside shells in the mountain rock by changing their origin: “*it is not a shell, if the rock comes from the mountains... it seems a shell, but it isn't*”, “*you think that this is a shell, but it isn't...*”, “*the stone grew and made a kind of shell which seems true*”.

## DISCUSSION

This small-scale research (40 pupils of nursery school in Pieraccioni, Gioncada & Bonaccorsi, 2018, and 40 pupils of the primary school in this work) has surely a limited statistical meaning; anyway it produced, in our opinion, some interesting qualitative results to trace children's reasoning about relevant concepts in Earth science. Unfortunately, it was possible neither to perform a longitudinal approach on the same individuals (the preschoolers we interviewed two years ago spread to many primary schools), nor to collect data before and after an educational sequence about the sedimentary rocks, as we actually did for the survey of the nursery children (Pieraccioni, Gioncada & Bonaccorsi, 2018).

Following the Piaget's classification of the five possible types of reaction by children during the conversation with the examiner (Piaget, 1929), we think that the collected explanations may represent the so called *liberated convictions*. With this expression Piaget collects all the cases in which a child makes an effort to reply to a completely new query after reflection, by using his/her own past experiences and ideas, even if he/she faces with the question for the first time: “The liberated conviction is thus, strictly speaking, neither spontaneous nor suggested; it is the result of reasoning, performed to order, but by means of original material (previous knowledge, mental images, motor schemes, syncretic associations, etc.) and original logical instruments (method of reasoning, natural tendencies of mind, intellectual habits, etc.)” (Piaget, 1929, p. 11).

It is noteworthy that none of the collected answers seems to fall into the group of *romancing* (Piaget, 1929), which probably affects several explanations by the preschoolers in the previous investigation.

The analysis of the data indicates that all the seven-years-old children note the presence of shells in the examined rock. This result is different from that we previously obtained in the nursery school (Pieraccioni, Gioncada & Bonaccorsi, 2018), where approximately one children over six didn't say to have seen the shells in the rock.

All the preschoolers (Pieraccioni, Gioncada & Bonaccorsi, 2018) and many of the seven-year-old children (this study) describe the rock referring to its surface, and do not relate the surface features to the characteristic of the interior: so, the description and possible explanation refer to shells that are “stuck” on the rock surface.

We noticed that the most of pupils of the primary school highlights the presence of other natural elements in the rock, *i.e.* little stones and sand, besides or even before the shells. This is in agreement with the fact that the older children are more experienced and, having already seen several examples of clam-shells, pebbles and sand, real or in photos or drawings in books and videos, they are able to recognize them in a rock they never saw before.

The percentage of children that do not express any explanation suitable to them for the shells in the mountain rock is higher than that of nursery school. Also the number of the given explanations differs between five- and seven-years-old children. For preschoolers the explanations given for the presence of shells (sea-related natural elements) in a mountain rock are very diversified: they range from no answer-nonsense answers (nearly one third of the pupils) to fantastic answers (anthropomorphism applied to shells or to animals), to the involvement of natural agents such as water and wind, to human action ("*someone put them up there*"). We can recognize nine different categories (Pieraccioni, Gioncada & Bonaccorsi, 2018). For older children, the explanation categories reduce to five (Table 1). The relatively few categories of the answers for seven-years old children with respect to five-years old children is in agreement with the child cognitive development. For example, none of the older children describes a process in which the rock and the shells move to meet together, as some five-years old children do, or suggest other naive animistic processes ("*I see also a lot of shells that had hidden into the rock*"; "*maybe the rock with the shells did not found a family and went away*"; Pieraccioni, 2018). It does not mean that the animistic thinking is absent in seven-years old children; with respect to preschoolers, they probably attribute consciousness to inanimate things only in particular occasions or, in some case, only to things that can move (second stage in Piaget, 1929).

As regards the occurrence of alternative conceptions about the rock formation, it is worth to note that the human intervention is claimed as explanation by a significant fraction of preschoolers and primary school children (similar to findings by Piaget, 1929); on the other hand, the same conception is expressed also by older students and pre-service teachers (Kusnick, 2002; Blake, 2005; Dal, 2009; Libarkin & Schneps, 2012).

The conception of "rock-made shells", with the negation of their organic and sea-related origin and the idea of a growth process ("*the stone grew and made a sort of shell which seems true*") closely recalls the idea - considered valid until the 16<sup>th</sup> century and beyond - of *in situ* generation of the fossils through a natural hidden power of the rock itself. The reported misconception about "pebbles that grow" (Kusnick, 2002) may have a similar origin.

As regards the "retrodictive reasoning" described by Libarkin & Schneps (2012), our data for 2<sup>nd</sup> class children indicate that several children use their knowledge of the present to infer an explanation for the shells in the rock. For example, five children knew that lakes and rivers could occur in mountain, therefore they justified the presence of shells in the rock by conjecturing that they were found in lakes or rivers, and not in the sea. On the other hand, just three out of forty children explicitly consider the possibility that changes have occurred at the Earth's surface over time. This reasoning implicates the vision of transformations happening with a temporal sequence and it may represent the first germ of a prospect of natural process defined in a time range.

In agreement with the constructivist learning theory, teachers should investigate pupils' ideas and find educational strategies to incorporate these information into a learning-teaching process. Our data indicate that it is possible to use common and familiar materials, such as rocks and shells, to promote a discussion about the possible transformations of geological materials in time. In the case of the mountain rock with shells, the cognitive conflict faced by children may be a key to prompt a retrodictive reasoning, as observed by Libarkin & Schneps (2012).



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