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AUTHOR Happs, John C.
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ABSTRACT

The Learning in Science Project has adopted the view that science teaching might be improved if teachers can be given some appreciation of students' views of the world and the beliefs, expectations, and language that learners bring to new learning situations. This investigation focuses on the views that children (N=34) may have about rocks and minerals. Information was obtained from interview protocols, word responses, and sorting tasks to examine ways in which: (1) children and adolescents view and describe rock/mineral samples and how they relate these ideas to rock/mineral origins and composition; (2) learners tend to categorize rocks/minerals; and (3) learners respond to key stimulus-words that are considered by earth scientists to be important in the study of rock/mineral samples. Results of the investigation indicate that the children focused on different attributes than those of earth scientists. In addition, their approach to developing categories for rock/mineral samples was in stark contrast to the approach likely to be taken by earth scientists (such as using appearance, origin, weight, and composition to categorize samples as either "rocks" or "not rocks"). (A discussion of earth scientists' views of rocks, minerals, crystals, and classification of the 15 samples used in the study is included.) (JN)

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ROCKS AND MINERALS

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WORKING PAPER No. 204

SOME ASPECTS OF STUDENT UNDERSTANDING OF ROCKS AND MINERALS

A Working Paper of the Science Education Research Unit

John C. Happs

May, 1982

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INTRODUCTION

Recent developments in cognitive psychology (Wittrock, 1974; 1978; Greeno, 1980) and its application to teaching strategies (Champagne et al., 1981; Osborne and Wittrock, 1982) have led to the view that a learner's prior knowledge must interact with incoming information to generate meaning. For learning to be effective and long lasting, this generated meaning must be linked, in a variety of ways, to information in long-term memory (cognitive structure). This approach emphasises the importance of an understanding of the ideas that learners bring with them to the learning situation, both in terms of helping teachers to understand more about the process of learning and in terms of helping to develop more effective teaching strategies.

In the past, many teachers have generally not seen the necessity to understand how teaching needs to be related to the learner's background and his/her current level of understanding. Lovell (1980) has placed this within the context of the classroom teacher. He highlights the situation whereby a student is introduced to a new topic during a science lesson and (s)he already has some prior ideas and a conceptual framework which relates to that topic. This framework of ideas may have been established from past personal experience involving previous teaching situations, exposure to news media and everyday encounters with familiar words.

Building upon existing conceptual ideas, or modifying available ideas within cognitive frameworks, would seem to be a more fruitful approach to teaching, rather than viewing the learner as a 'blank slate' needing a completely new cognitive framework (see Gilbert et al., 1982).

The Learning in Science Project (Osborne et al., 1981) has taken a pragmatic research approach, emphasising the philosophy that science teaching, at all levels, might be improved if teachers can reach a better appreciation of the learners' views of the world. The Learning in Science Project has focussed on the broader ideas and alternative frameworks that the learner is likely to take to the science learning situation. More specifically, the Learning in Science Project has probed those beliefs, ideas and viewpoints that learners employ during science lessons. This emphasis has not been evaluative, rather it has attempted to obtain this kind of information by means of small-scale, in-depth research that can relate its findings to science teaching essentially at the Forms 1-4 levels.

This investigation looks at the topic "rocks and minerals" and attention has been brought to bear on the knowledge, ideas and language that learners might possess in this area. The topic "rocks and minerals" is seen to be an important teaching area within the earth sciences (Happs, 1981) and this topic is included in the Infants to Standard 4 syllabus, in Section 4 (level 4) of the Science Form 1-4 Draft Syllabus and Section 8 (level 5) of the same syllabus.

Information has been obtained from interview protocols, word response and sorting tasks associated with rocks and minerals. Some understanding has emerged in the following areas:

(i) Ways in which children and adolescents view and describe rock and mineral samples and how they relate these ideas to rock and mineral origins and composition;

(ii) Ways in which learners tend to categorise rocks and minerals;

(iii) Ways in which learners respond to key stimulus-words that are considered by earth scientists, to be important in the study of rocks and minerals.

Prior to the examination and discussion of results from this investigation, it might prove useful to consider the 'core knowledge' from these three areas that an earth scientist may perceive as being of importance.

WHAT IS A MINERAL?

We frequently hear of certain plant foods that will provide 'minerals' for plant growth and vitamin pills which will provide the human body with 'minerals' that are essential for good health. A miner may consider a mineral to be any material that is of economic value and which can be removed from the Earth. Examples are likely to be coal, oil and clay.

The term 'mineral' is often used loosely in everyday language whilst the earth scientist tends to be more precise when the term is used. A mineral refers to an inorganic substance which has a definite chemical composition and an ordered atomic arrangement. The inclusion of the rider 'an ordered atomic arrangement' implies that minerals are crystalline rather than amorphous.

About 2,000 minerals are known to exist, although only about 20 of these minerals make up more than 95 percent of the Earth's crust. All rocks contain one or more minerals. Minerals are commonly dispersed throughout rocks although they can be concentrated to form mineral deposits such as ore bodies. Some important rock-forming minerals, used as examples in this investigation are:

(a) quartz: This mineral is commonly found in igneous rocks such as granite. Sandstones are sedimentary rocks which are largely made up of angular and occasionally well-rounded grains of quartz [silicon dioxide]. Quartz is also a common constituent of many metamorphic rocks. It is a common mineral of widespread occurrence and is readily distinguished from calcite by its hardness (quartz has a hardness of 7, on a scale of 1-10, whilst calcite has a hardness of 3) and from feldspar by its lack of cleavage (feldspar usually has good cleavage). The colour of minerals alone does not usually offer a reliable means of identification and quartz is no exception. The colour of quartz varies widely from being colourless to white, purple, pink, yellow, red, green and black.

(b) feldspar: The feldspars are the dominant constituents of most igneous rocks and thus are of volumetric importance. Chemically the feldspars are potassium, and sodium to calcium, alumina silicates. Orthoclase (sample used in this investigation) occurs as an important component of the more acid igneous rocks such as granite and rhyolite. It shows perfect cleavage, a hardness of 6, with a colour range through white, red, flesh-coloured and colourless.

(c) biotite: This is a common rock-forming mineral which occurs as a primary component of 'acid'[1] igneous rocks. It is commonly found as a mineral of metamorphic origin, e.g. biotite-schist. Chemically, biotite is a magnesium, iron, aluminum and potassium silicate. It is a black mica [sometimes it is greenish-black] which shows perfect cleavage, to yield thin flexible elastic sheets. Its hardness is $2^1/2$ to 3 and its black colour and micaceous cleavage are important distinguishing properties.

1. The term 'acid' refers to the silicon dioxide content of a rock rather than pH e.g. an acidic rock has more than 65% S_iO_2.

WHAT ARE CRYSTALS?

The early Greeks were aware that the mineral quartz often occurred in a characteristic form, bounded by flat faces. Because the mineral was often transparent, it was thought to have resulted via water freezing under intense cold. The name 'Krustallos' (clear ice) was given and came to be the term used for any mineral which displayed such form.

Crystals are homogeneous solids, bounded by plane surfaces, having a definite symmetry which is an expression of the internal arrangement of the component atoms.

The majority of minerals are crystalline, even if this is not immediately obvious to the naked eye because of the extremely small size of the crystals.

WHAT ARE ROCKS?

Rocks may be defined as mineral aggregates composed of one or more minerals. Thus a heterogenous rock sample can be examined to reveal the presence of a number of different homogeneous minerals.

It is worth noting that the dividing line between rocks and minerals is not always clearly defined and, when a single mineral occurs in great quantity to form a rock mass, the name of the mineral is also given to the rock. Some rocks then may be made up of one mineral only, e.g. the rock 'marble' consists of the single mineral 'calcite' and the rock 'dunite' consists essentially of the mineral 'olivine'.

Looking at a large rock collection for the first time gives the impression that rocks are confusingly diverse, differing in colour, texture and hardness. Some are layered whilst others have no structure that is apparent to the naked eye. Despite this seemingly endless variation, we can group all rocks into three main families, on those characteristics which reflect their genesis. These groups are:

1. IGNEOUS ROCKS: These rocks are formed by the cooling and solidification

of magma[2] and lava and consist of an interlocking aggregate of silicate minerals. Some important igneous rocks [used as examples in this investigation] are:

(a) granite: This is the best-known of the deep-formed [plutonic] igneous rocks. It is hard and relatively resistant to weathering, being frequently used in monumental sculpture and construction. It is a coarse-grained rock with feldspar and quartz being the chief minerals, along with biotite. These individual minerals can often be distinguished by the naked eye.

(b) ignimbrite: This is a rock that has formed via the flowage and deposition of volcanic ash. Ignimbrites are commonly referred to as Hinuera stone, Tokoroa stone or Putaruru stone.
The eruptions which give rise to ignimbrites are violent and the eruptive products have great mobility which can result in material covering large areas with thicknesses of several hundred metres. The deposits retain substantial heat, for some time, and this results in the particles being welded together.

(c) obsidian: When magma is ejected from a volcano to produce lava flows many of the resulting rock types are fine-grained because of rapid cooling. Obsidian is a dense natural glass which has a chemical composition similar to granite. Although it is a dark-coloured rock, thin pieces of obsidian are translucent. The rock can be identified by means of its black[3] colour and its marked curving [conchoidal] fracture which is similar to that which appears when man-made glass breaks.

(d) pumice: This rock has a similar composition to obsidian and is also formed by the rapid cooling of 'acidic' magma. Pumice is usually a white solidified glassy froth which has many cavities [vesicles] formed by gases which escape through the viscous, quickly cooling lava. The presence of trapped gases within the pumice make it sufficiently buoyant to float in water.

(e) scoria: This rock is produced from congealed basic lava which has a high proportion of ferro-magnesian minerals. The upper parts of

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2. The glossary in Appendix A, offers an explanation of those terms which are commonly used by the earth scientist and which are pertinent to this paper. Pyroclastic rocks, e.g. ignimbrite, pumice and scoria, have been grouped under 'igneous rocks' for the sake of simplicity.
3. Obsidian can also be green and brown in colour.

this lava flow typically contain many cavities which are formed by escaping gases which come out of solution as the magma reaches the surface. Scoria is dark-red, or black in colour with a rough surface.

2. SEDIMENTARY ROCKS: These rocks are formed by the accumulation, consolidation and 'cementation' of sediment. The particles of sediment are derived from pre-existing materials which are transported, deposited and 'cemented'. Other sedimentary rocks are produced by chemical action, either directly or via organic activity. Some important sedimentary rocks (used as samples in this investigation) are:

(a) conglomerate: These coarse-grained sedimentary rocks are made up of rounded or sub-angular fragments larger than 2mm in diameter. Such particles, usually comprising rock fragments, are set in a matrix of finer material, such as sand or silt. The coarse fragments which form conglomerates may be transported in swift rivers, glacier ice or by wave action. Conglomerates often grade laterally into sandstones.

(b) sandstone: This rock is made up of rounded or angular fragments with diameters of .02 to 2mm.[4] The grains are usually quartz, feldspar and rock fragments, commonly 'cemented' together.

(c) greywacke: The most abundant rock in New Zealand, greywacke is a very hard, grey-coloured sandstone which contains significant amounts of quartz, feldspar and rock fragments within a clay matrix. Greywacke is commonly used for road 'metal' and concrete aggregate.

3. METAMORPHIC ROCKS: These rocks are formed within the Earth's crust by the transformation, in the solid state, of pre-existing rocks. This change results from high temperature, high pressure or both.

Approximately 95 percent of all rocks that are within the Earth's crust are igneous or metamorphic, yet most of the rocks that we actually see on the surface of the Earth are sedimentary. This observation reflects the fact that igneous and metamorphic rocks are products of internal processes, whereas sedimentary rocks are essentially the result of surface processes which are ongoing at all times.

4. The soil scientists particle size scale is adopted here.

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Some important metamorphic rocks (used as examples in this investigation) are:

(a) gneiss: This may simply be metamorphosed granite or of a far more complex origin. Gneiss is generally a coarse-grained rock which shows compositional banding. The dark bands may be biotite or hornblende, with white bands of quartz and feldspar. Gneiss does not show any pronounced parting along the banding.

(b) schist: This represents a more highly metamorphosed rock than gneiss. It displays a parallel alignment of flaky minerals and schists tend to split along wavy, uneven surfaces. Mica schist is the most widespread metamorphic rock in New Zealand and results from the metamorphism of mainly greywacke.

(c) marble: This is a metamorphic rock which is commonly formed by the recrystallisation of limestone and its later change by heat and pressure.

The addition of dilute hydrochloric acid to marble will result in effervescence and the evolution of carbon dioxide gas.

SORTING THE SAMPLES

The second phase of the investigation entailed the classification of the rock and mineral samples by learners. However, it should prove useful at this stage to examine the ways in which an earth scientist is likely to categorise the fifteen samples previously described.[5]

The earth scientist would be likely to divide and group the 16 samples, simply, into 5 groups on the basis of their mode of formation whilst using the criterion of whether, or not, the samples represent minerals or rocks. The resulting groups are likely to be;

(i)	rock-forming minerals:	biotite (sample No. 1)
		feldspar (sample No. 3)
		quartz (sample No. 11)
(ii)	sedimentary rocks:	conglomerate (sample No. 2)
		greywacke (sample No. 6)

5. A sample of a housebrick fragment was also included to provide an example of a man-made 'rock-like' material.

sandstone (sample No. 12)
greywacke pebble (sample No. 15)

(iii) igneous rocks: granite (sample No. 5)
ignimbrite (sample No. 7)
obsidian (sample No. 9)
pumice (sample No. 10)
scoria (sample No. 14)

(iv) metamorphic rocks: gneiss (sample No. 4)
marble (sample No. 8)
schist (sample No. 13)

(v) man-made material: housebrick fragment (sample No. 16)

This classification scheme could well be extended by looking more closely at the origin of rocks.[6] Further information on this aspect is provided in Appendix B.

THE INVESTIGATION

Thirty four students (4 x F1,[7] 5 x F2, 6 x F3, 6 x F4, 3 x F5, 5 x F6, 5 x F7[8]) participated in this investigation and these were selected from three intermediate and six co-educational secondary schools. Each student was identified by his/her science teacher, who was asked to choose class members of 'average scientific ability'.[9]

In order that student samples were kept fairly heterogeneous, not all students from any one age level were interviewed from the same school.

6. The further classification of igneous, sedimentary and metamorphic rocks becomes quite complex and it would be inappropriate to venture into this area, within the scope of this paper. The reader who is interested in finding out more about the classification of rocks and minerals is referred to texts such as Cox, K.G. et.al., 1967. The Practical Study of Crystals, Minerals and Rocks, London, McGraw-Hill.
7. F1 = Form 1 (11 year olds); F2 = Form 2 (12 year olds).
8. All Form 6 and 7 students took English, geography and at least one science option.
9. A number of students appeared, to the investigator, to be somewhat above average.

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During the individual interviews each student was asked to examine the various rock and mineral samples whilst later questioning elicited as much information as possible about the samples.

Each interview lasted approximately 30-45 minutes and a discussion of observed samples was encouraged, in terms of the students' own language and ideas. It was emphasised, prior to each interview, that there would be no emphasis placed, or comments passed, on 'right' or 'wrong' answers. Every interview was kept as informal as possible so that a non-threatening atmosphere might be maintained throughout. Students were fully informed about the purpose behind each interview and the need to use a tape-recorder.[10]

Thirteen cards were shown in sequence, to each student at the end of the 'sample phase'. A stimulus word[11] was written on each card so that students were provided with another opportunity to give more information with regard to rocks and minerals.

The interview ended with a 'sorting-phase' whereby each student was asked to place all rock and mineral samples in front of him/her. The student was then asked to sort, or group, the samples in the way they thought they should be arranged, according to common properties. When this task was completed, students were then asked to provide the reasons for the categories they had generated and to give 'labels' for each category, wherever possible. In this way it was hoped to gain some insight into how the learner might group rocks and minerals, in comparison to the earth scientist.

The responses to the three phases of the investigation will now be summarised, bearing in mind that the questions posed were open-ended, usually starting with: "What do you see there?", when a sample was placed in front of the student.

The terms 'rock' and 'mineral' were only used if they were provided by the student, so that once a sample had been described as a rock, then the

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10. Permission to use a tape-recorder was sought from each student and full confidentiality assured.
11. The stimulus words were: rock, mineral, sedimentary, igneous, metamorphic, quartz, feldspar, granite, pumice, greywacke, sandstone, marble, schist.

interview could pursue the student's meaning of that word, using questions such as: "What is a rock - in your meaning of the word?"

WAYS IN WHICH CHILDREN AND ADOLESCENTS VIEW AND DESCRIBE ROCK AND MINERAL SAMPLES

This first part of the investigation showed that pupils, in describing rock and mineral samples, focus on quite different attributes to those of the earth scientist. Here we will summarise these results:

(a) Firstly the word mineral tended not to be associated with any of the samples. In the case of biotite (a rock-forming mineral) for instance, none of the students considered that the sample might be a mineral, nor was the term 'mineral' applied to any of the samples. Learners generally applied the word 'rock' to the mineral samples and tended to use the word in an intuitive way:

> "I'd just say it's (biotite) a rock because I know it's a rock."[12] (305)

> "It (feldspar) just looks like a rock - I don't know." (501)

The idea of students just "having a feeling" that something is a rock, was quite prevalent:

> "I don't know - I've just got this feeling it's (gneiss) a rock." (403)

(b) Secondly, terms such as 'crystal'[13], 'stone'[14] and 'pebble'[15] were used to describe the samples in a loose, non-scientific way with learners

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12. The 'everyday' meaning of the word 'rock', as provided by the Concise Oxford Dictionary, refers to:
    "Solid part of the earth's crust underlying soil ... a large detached stone, boulder."
13. The 'everyday' meaning of the word 'cyrstal', as provided by the Concise Oxford Dictionary, refers to:
    "A clear transparent ice-like mineral."
14. The 'everyday' meaning of the word 'stone', as provided by the Concise Oxford Dictionary, refers to:
    "A piece of rock of any shape, detached from the earth's crust and of no great size, or a single piece used or usuable in building or roadmaking or as a missile."
15. The 'everyday' meaning of the word 'pebble', as provided by the Concise Oxford Dictionary, refers to:
    "A small stone worn and rounded by action of water."

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tending to consider factors such as physical appearance, shape, or the weight of an object as criteria for their identification. For instance, the 'everyday' (dictionary definition) meaning for the word 'stone' was considered and applied by six students (1 x F1, 1 x F2, 1 x F3, 3 x F4) to describe the sample of feldspar, which was a tabular piece measuring approximately 30 x 20 x 10mm. It seemed to be the size of the sample which largely determined whether, or not, the term 'stone' was used:

> I. "Oh, I see ... it's a smaller piece so it's a stone?"
>
> P. "Yes." (102)

(c) Thirdly, some of the larger samples[16] were readily described, by most students, as 'rocks'.

> "Yes - everything that's this size, or something bigger, is just a rock to me." (305)

The 'smoothness', or otherwise, of a sample was noted and used as a criterion by some students.

> I. "So you think we might have a piece of rock?" (holding conglomerate)
>
> R. "Yes - 'cos rocks are jagged." (205)

The weight of individual samples was frequently 'assessed' by students prior to them deciding whether, or not, samples were to be called rocks:

> I. "Well, why is that a rock?"
>
> M. "It's got the weight." (101)

The sample of greywacke (a sedimentary rock) appeared to be more akin to what most students generally regarded as being a 'typical rock'. Twenty eight students (2 x F1, 5 x F2, 2 x F3, 6 x F4, 3 x F5, 5 x F6, 5 x F7) were confident in describing this sample as a rock. However, once again, the reasoning behind this opinion usually failed to match up with the scientists' view of a rock:

> I. "You seem very sure about that. Now why should that be a rock?"

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16. None of the samples measured more than 120mm across its longest face.

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N. "It's heavy and it's lumpy ... and the size ... probably the colour mainly - dull colours." (204)

The terms 'ordinary' and 'dull' were commonly used, even by those students who did not see the greywacke sample as being a rock.

"It's an ordinary stone." (103)

~~Students' dependence on factors such as 'weight' and 'colour'~~ when deciding whether a sample was a rock, proved misleading in the case of the pumice. This sample (an igneous rock) was the most widely recognised, with only three students (1 x F1, 2 x F2) not being able to identify it. Despite this majority recognition of pumice, only six students (2 x F2, 1 x F3, 1 x F6, 2 x F7) felt confident that they were looking at a rock.

(d) Learners frequently considered factors such as physical appearance, shape or the weight of a sample as criterial attributes. Non-scientific language is commonly brought into play, thus we often hear of vehicles 'skidding in the gravel'[17] with the implication being made that gravel is made up of small-sized, loose material, usually found on the side of roadways.

The earth scientist is likely to place size ranges on a number of particle terms, with the exception of the word 'stone', so that they take on more specific meaning. Although the word 'stone' does appear in literature relating to the earth sciences, e.g. stone-reef; stony-desert, no definite size range is placed upon a 'stone'.

The geologist and soil scientist place precise size boundaries on a number of particles, although their individual scales are slightly different.

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17. The 'everyday' meaning of the word 'gravel', as provided by the Concise Oxford Dictionary, refers to:
"Coarse sand and small water-worn or pounded stones, much used for laying paths and roads."

Size Term	Geologist's Scale (mm)	Soil Scientist's Scale (mm)
boulder	more than 256	more than 200
cobble	256 - 64	200 - 50
pebble)) gravel[18]	64 - 4	50 - 4
granule)	4 - 2	4 - 2
sand	2 - .063	2 - .02
silt)	.063 - .004	.02 - .002
clay) mud	less than .004	less than .002

(e) As anticipated, students were, generally, not able to carry out the experience-specific task of rock and mineral identification. Most learners were able to offer limited descriptions of each sample, using everyday terminology, although few were successful in arriving at correct names for any of the samples. In the case of granite (1 student (603) thought the sample was like granite), ignimbrite (1 student (602) used the term 'Hinuera Stone'), marble (1 student (601) used the term 'marble' but doubted that the sample was a rock), obsidian (4 students (1 x F4, 1 x F5, 1 x F6, 1 x F7) identified the sample correctly), pumice (only 3 students (1 x F1, 2 x F2) were not able to identify the sample by name, but only 6 of these students (2 x F2, 1 x F3, 1 x F6, 2 x F7) felt that the pumice represented a rock), sandstone (1 student (703) provided its correct name), scoria (6 students (1 x F1, 1 x F3, 1 x F6, 3 x F7) were able to provide the correct name). The housebrick fragment was recognised as such, by 23 students (3 x F1, 2 x F2, 4 x F3, 3 x F4, 2 x F5, 4 x F6, 5 x F7) although only 8 of these students (2 x F2, 1 x F3, 1 x F6, 4 x F7) realised that it was actually man-made. Apart from those students indicated in brackets, no others described or labelled the samples in a way that approximated the earth scientists.

In summary, the ways in which children and adolescents use language in this area, and its application to the description of individual rock and mineral samples, is shown in table 1, along with the kinds of modifications which are recommended, from the earth scientists' point of view:

18. Size definitions vary for the term 'gravel'. In this paper gravel is taken to include 'granules' and 'pebbles' c.f. the Wentworth size scale which regards 'gravel' as being any particle over 2mm in diameter.

	LEARNERS' VIEWS	MODIFICATIONS NEEDED
1.	The term 'rock' is largely used in a non-scientific way, with criteria such as 'weight', 'colour', 'size' and 'jaggedness' being employed, e.g. a relatively <u>large</u> sample of <u>dull-looking</u> greywacke rock was readily described as a rock by 82 percent of students interviewed.	Students need to be able to examine a few key rocks which contain individual minerals. Even if individual minerals cannot be identified, a good light-source, and hand lens will show many rocks to be made up of minerals. Granite is a good example.
2.	Rocks are commonly described and classified as 'crystal rocks' or 'normal rocks', etc. Colour again, appears to be important to students when they classify samples of rocks and minerals.	A few of the more important rocks shoud be classified according to their mode of formation. Straightforward examples, such as coarsely-crystalline granite, sandstone and schist can be used to contrast patterns of formation.
3.	The term 'crystal' is frequently used by students when they come to describe both rocks and minerals. The word 'crystal' tends to be used only if the particular sample is sufficiently attractive to them.	The colour and shape of individual samples can be quite misleading during identification. Crystals are bounded by plane surfaces and have a definite symmetry, yet this is often difficult to see in rock samples. Photographs or slides of 'ideal' examples of crystals are needed if actual samples are unobtainable.
4.	The term 'stone' is used as frequently as the term 'rock'. Students tend to use the criteria of size and attractiveness when deciding on which term to use.	The term 'stone' does not take on any scientific meaning and is generally not used when describing rock and mineral samples. The two meanings should be compared.
5.	The term 'mineral' appears to have little or no connection with the 'fabric' of rocks, as far as learners are concerned.	Minerals are commonly dispersed throughout rocks as inorganic substances with a definite chemical composition. The everyday meaning of 'mineral' should be contrasted with the scientific view.

TABLE 1: Learners' Views of Terms Such as 'Rock', 'Crystal', 'Stone', and 'Mineral'.

THE CATEGORISATION OF ROCKS AND MINERALS BY LEARNERS

This phase of the investigation provided useful information concerning those aspects of the learners' views of rocks and minerals, as reflected in the way they approached the task of classifying the samples provided.

Students placed all 16 samples on a table in front of them and were then asked to imagine that the collection belonged to them and they had the task of sorting them into various groups for display purposes. They were told that they could have as many, or as few groups, as they wished and that each group was to have a suitable label, indicating why they had been sorted in that way. The learners' approach to developing categories for rock and mineral samples was in stark contrast to the approach that is likely to be taken by the earth scientist.

A number of interesting points have emerged from this section of the investigation and the following is a summary of the more important results.

(a) Students tended to divide the samples initially into those they called 'rocks' and others that were 'not rocks'.

(b) Fifteen categories were generated for those samples which were identified as being 'rocks'. These could be 'collapsed' to provide seven groups using the following criteria for categorisation: appearance; origin; weight; composition; changes; useage; location.

(c) Collapsing the eleven categories for samples indentified as not being rocks, led to eight groups with the following criteria being adopted: appearance; origin; weight/strength; composition; actual names; stones; comparisons; familiarity.

(d) Four common groups emerged from the categories 'rocks' and 'not rocks'. These groups were: appearance; origin; weight and composition.

It is interesting to note that the earth scientist is likely to identify samples according to their mode of origin and composition. Furthermore, the appearance of rock samples is frequently used to provide category names. See Table 2.

A simple categorisation scheme proposed by one earth scientist is shown below:

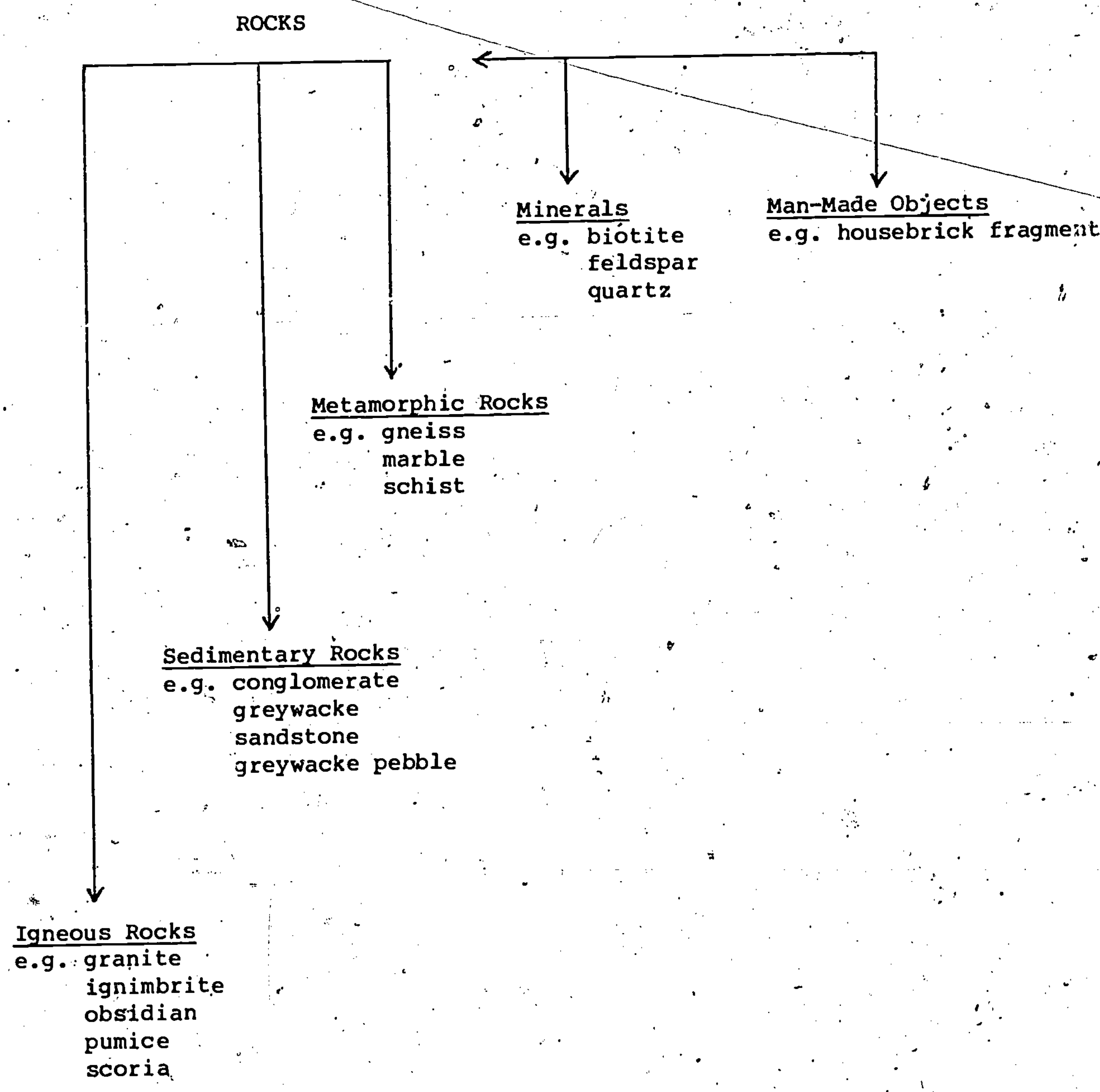

TABLE 2: A Simple Categorisation System (for the samples used in this investigation) Proposed by One Earth Scientist.

The initial grouping stems from a knowledge of the terms 'rock' and 'mineral' and the ability to recognise key examples for subsequent categorisation.

Finally, the group of 'rocks' is subdivided further, depending on mode of origin, as recognised in the external appearance of individual samples.

The initial categorisation, by learners, using the labels of 'rock' and 'not rock', highlights the difficulties that are likely to be encountered when the term 'rock' is not understood from a scientific standpoint. When the scientific meaning of the word 'rock' is not appreciated learners are likely to generate their own, idiosyncratic concept of 'rock'. This is likely to take on non-scientific meaning and this meaning, could be influenced by the 'plain' appearance of some samples:

I. "So that word 'rock' then - to you - means something that's not special?"

C. "Yes - just a plain something - you see on the road or - whatever." (601)

The 'weight'[19] of a particular sample is rarely used by the earth scientist in a diagnostic scheme, yet the novice considers this feature to be an important criterial attribute of a rock. This was evident at all age levels.

"What I call a rock - I go on weight - I don't think it's right scientifically, but I just go on weight." (704)

This use of non-scientific language occurs at every level and, those opinions expressed by older students, are similar to the views held and expressed by younger students:

"Something that's really hard that - can't break unless it's got a lot of force put on it." (104)

The need for students to have a clear idea of the word 'rock' cannot be stressed too much. This became evident in parts (i) and (iii) of this investigation also.

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19. Density can be a diagnostic property for some minerals e.g. barite.

The lack of appreciation of the scientific meaning behind the word 'rock' is likely to be aggravated by the fact that no student was able to use the term 'mineral' in the scientific sense.

The term 'stone' took on real meaning to many students and the word was clearly preferred to the terms 'rock' and/or 'mineral':

> "I would probably call that stone - or something to do with that. I wouldn't call it (ignimbrite) a rock though." (304)

Let us consider two specific examples of the ways in which learners categorised samples. These examples are selected because they examplify the novices' use of a much wider variety of criteria when classifying rocks and minerals:

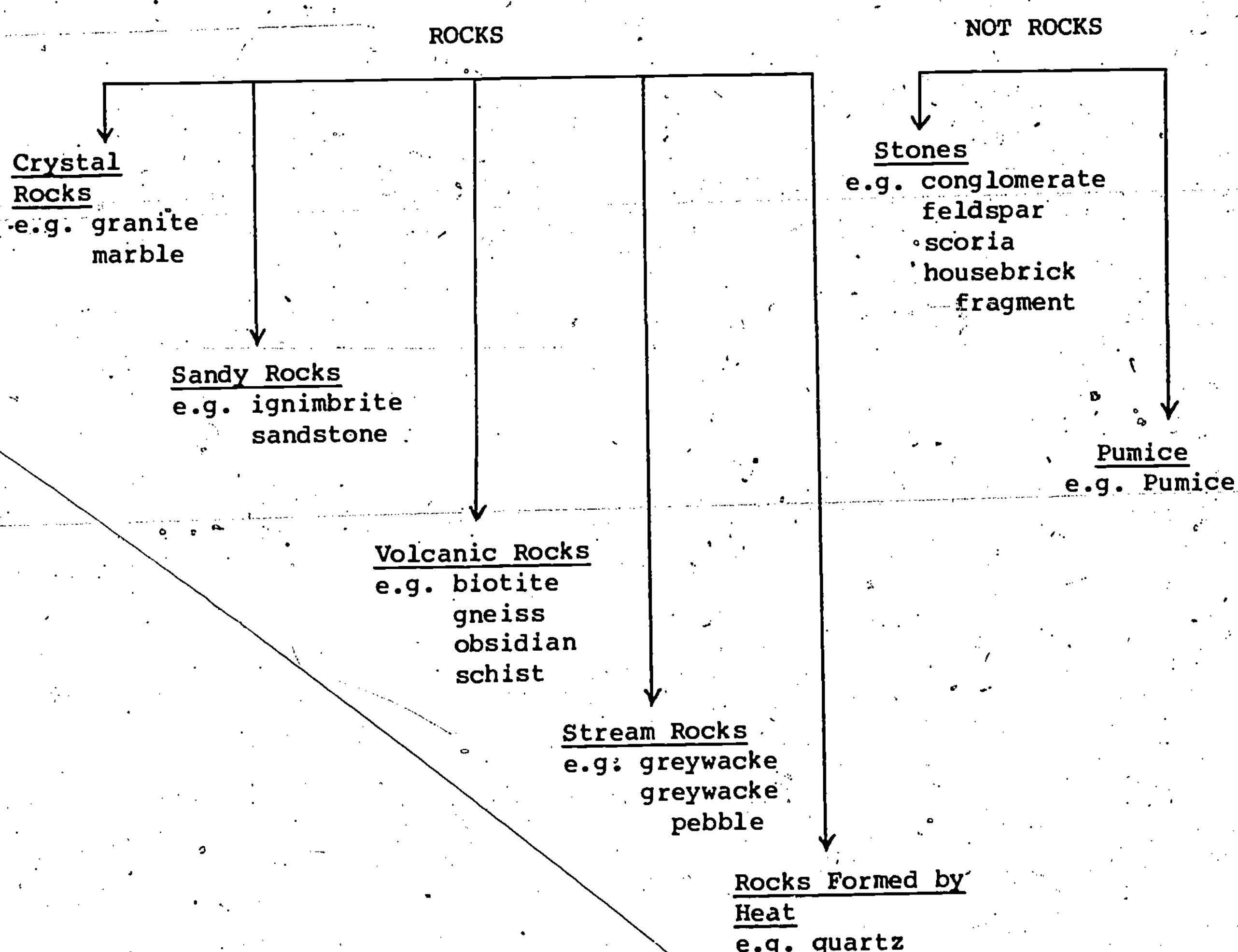

TABLE 3: Categorisation Scheme as Proposed by a F1 Student.

The use of non-scientific language is evident in the categorisation scheme shown in Table 3. This proposal offers terms such as 'stream rocks', 'sandy rocks' and 'crystal rocks'. 'Stones' are seen to be something quite distinct from rocks whilst pumice is simply called as 'pumice' with no affiliation to rocks or minerals.

Similar difficulties were encountered when more experienced students categorised the samples although more appropriate selection was sometimes experienced:

ROCKS

- Volcanic Rocks
  e.g. obsidian
  pumice
  scoria
- Oridnary Rocks
  e.g. greywacke
  greywacke
  pebble
- Exotic Rocks
  e.g. biotite
  feldspar
  quartz
- Sedimentary Rocks
  e.g. sandstone
- Crystalline Rocks
  e.g. gneiss
  granite
  marble
  schist

Man-Made Objects
e.g. conglomerate
ignimbrite
housebrick
fragment

TABLE 4: Categorisation Scheme as Proposed by a F7 Student.

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This category scheme, as shown in Table 4, represents one of the better attempts by a student to group the samples in a scientific manner. Volcanic and sedimentary rock groups were selected in an appropriate manner with correct examples.

Failure to recognise the samples of conglomerate and ignimbrite led to them being placed in the 'man-made' category, alongside the housebrick fragment.

This scheme typically represents the joint usage of both scientific and everyday category names. Words such as 'ordinary' and 'exotic' being used to generate categories for samples that were not recognised as having a specific origin or else for mineral samples which were not recognised as such.

Ways in which learners respond to key stimulus-words that are seen, by earth scientists, to be important in the study of rocks and minerals

There have been a number of instances (albeit small), throughout this investigation where learners, across all age rangers, have provided scientifically acceptable ideas about some of the stimulus-words. In this way, a minority of students were seen to hold views, about aspects of rocks and minerals, which were compatible with the earth scientists' perspective. These isolated instances however, appeared to be in contrast to the ways in which the majority of students perceived the terms 'rock' and 'mineral'.

It may be pertinent to look at a summary table of findings which emphasise some of these points. This information stems directly from the phase of the investigation whereby learners were shown specific stimulus-words and were asked for their explanation. The information that was gleaned from this phase reinforced, in many ways, some of the findings from earlier phases of the investigation:

	SCIENTISTS' VIEW	LEARNERS' VIEW	IDIOSYNCRATIC VIEWS.
WHAT IS A ROCK?	A rock, simply speaking, is a mixture of various minerals. However, some rocks may be made up of only one mineral.	1) Something hard 2) Heavy things 3) Dull coloured objects The earth scientists' view was rarely provided.	1) Something you just find 2) Something that just looks like rock 3) organic material 4) compressed soil
WHAT IS A MINERAL?	An inorganic substance, having a definite chemical composition and ordered atomic arrangement. Simply speaking, minerals make up rocks.	1) Rocks are made up of minerals (9%) A spectrum of ideas determined by everyday meanings such as a) mineral water b) minerals and vitamins c) mineral resources e.g. oil, coal	1) small stones 2) precious things

TABLE 5: A Comparison of Learners' and Scientists' Views of the terms 'rock' and 'mineral'.

It would appear that difficulties do exist in getting the learner to appreciate the scientists' view of terms such as 'rock' and 'mineral'. The student is likely to offer an interpretation of such words, which are moulded by 'everyday' language and 'everyday' criteria such as 'a rock is hard', or 'rocks are heavy and solid', or grey in colour. In this regard, considerable confusion emerges as to the differences between the word 'rock' [which is a valid and scientifically definable term] and 'stone' [which readily takes on non-scientific meaning and is generally not part of the earth scientists' vocabulary].

This point can be made by referring to an extract from an interview with an experienced science teacher who had majored in biology but had little experience in the earth sciences:

I. "What is a rock - in your meaning of the word?"

K. "Rock is a fairly dense - particle. I use the word 'particle' here - I use the word 'rock' - something that has got - sort of - a mass of - what would weigh a kilogram plus. Anything less than a kilogram is probably getting back into the 'stone' size. So a rock is something fairly substantial that's got considerable mass."

Similar problems were encountered with the learners' views of the term 'mineral'. A whole range of 'everyday' meanings emerged whilst the earth scientists' viewpoint was totally unappreciated by students in this investigation.

If the terms 'rock' and 'mineral' are not understood in their scientific context then we might predict that the classifications of rocks and the terms 'sedimentary', 'igneous' and 'metamorphic' may not be perceived by the student, in the way that teachers think they might be perceived.

The following table summarises the learners' views of the terms 'sedimentary', 'igneous' and 'metamorphic', whilst looking at the scientist's view of these terms:

	SCIENTISTS' VIEW	LEARNERS' VIEW	IDIOSYNCRATIC VIEWS
SEDIMENTARY	Generally speaking, a category of rock formed by the accumulation and cementation of sediment. Transported particles derived from pre-existing materials.	1) No ideas (38%) 2) A kind of rock (41%) 3) An appreciation of sedimentation shown (6%) 4) Spectrum of ideas including notions of genesis via volcanoes and/or heat.	1) Rocks of the ocean 2) Hard rock 3) Something organic 4) Jagged rocks
IGNEOUS	Generally speaking, a category of rock, formed by the cooling and solidification of magma.	1) No ideas (44%) 2) A kind of rock (35%) 3) Association with fire or volcanic eruptions (29%)	1) Coloured rock 2) Shiny rock
METAMORPHIC	Generally speaking, a category of rock, formed by changes to pre-existing rocks. Such changes are typically caused by high temperature, high pressure or both.	1) No ideas (54%) 2) A kind of rock (35%) 3) A rock that has been changed by some means (6%)	1) Something to do with plants 2) Layered rock 3) A rock found in a stream

TABLE 6: A Comparison of Learners' and Scientists' Views of the Terms 'Sedimentary', 'Igneous' and 'Metamorphic'.

Difficulties immediately arise when, for instance, the learner associates the terms 'sedimentary', 'igneous' and 'metamorphic' with kinds of rock yet has not grasped the scientific meaning of the term 'rock'. Clear examples have been cited to show how even the more experienced student will readily accept that sandstone, for instance, can be 'sedimentary formed', yet the same student will deny that it constitutes a rock. To reinforce this pattern of thinking, there was a more marked tendency for learners to acknowledge that pumice has a volcanic origin whilst not recognising that it is a rock.

Comment, with regard to individual rock and mineral stimulus-words, revealed that students generally had little or no background information to offer. This problem appears to be compounded by the fact that the identification and description of individual rock types hinges greatly on the learners' ability to think in terms of what is meant by 'a rock' and their modes of format n. If this is not achieved then students will only acquire superficial ba ound information via image-recognition and rote learning.

Once again, it was noted that students frequently indicated that they had heard of rock names such as 'granite' yet, in this particular case, not one of the students was able to identify the rock from amongst the samples provided. The topic 'rocks and minerals' cannot be taught as a series of definitions of rock types, along with written examples. First-hand experience must be provided in the form of actual samples of rocks and minerals, with ample opportunity for students to examine these closely.

It might be argued that a much larger sample size and/or an extended written survey may not substantiate these findings yet, in view of past research and many off-the-record discussions with other students and teachers, I would confidently predict that, on the whole, these findings relect fairly accurately the level of concept understanding, in this topic area, in New Zealand schools.

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APPENDIX A - GLOSSARY OF TERMS

Biotite: A common rock-forming mineral known as black mica. Biotite is frequently found as a mineral of metamorphic origin, e.g. biotite-schist.

Boulder: A rock fragment generally exceeding 200mm in diameter.

Cobble: A rock fragment, generally ranging between 50 and 200mm in diameter.

Conglomerate: A coarse-grained sedimentary rock made up of rounded or sub-angular fragments, larger than 2mm in diameter. These fragments, are set in a matrix of fine-grained material such as silt or sand.

Crystal: An homogenous solid, bounded by plane surfaces, having a definite symmetry which is an expression of the internal arrangement of the atoms.

Feldspar: The dominant mineral type in most igneous rocks. Chemically, the feldspars are the aluminous silicates of potassium, sodium and calcium.

Gneiss: A coarse-grained metamorphic rock which shows compositional bending and parallel alignment of minerals. Gneiss may simply be metamorphosed granite or of a far more complex origin.

Granite: A coarse-grained, igneous rock composed of quartz, feldspars and micas.

Gravel: A natural, loose accumulation of rock fragments with a size range of 2-50mm in diameter.

Greywacke: A very hard, grey-coloured sandstone which contains significant amounts of quartz and feldspar.

Igneous Rock: A rock that has formed by the cooling and solidification of molten or partly motlen magma. Igneous rocks typically consist of an interlocking aggregate of silicate minerals.

Ignimbrite: An igneous rock that has formed via the deposition and consolidation of volcanic ash.

Lava: A general term for molten extruded material. The term is commonly used to refer to the rock that has solified from the molten lava.

Magma: Naturally occurring fluid molten rock material which is generated, at depth, beneath the surface of the Earth. Igneous rocks originate from magma.

Marble: A metamorphic rock, commonly formed by the recrystallisation of limestone and its later hardening by heat and pressure.

Metamorphic Rock: A rock which has resulted via the transformation of pre-existing rocks as a result of high pressure, high temperature or both.

Mineral: A naturally occurring elemen. or compound which has a definite chemical composition and an ordered atomic arrangement.

Obsidian: A dense, dark coloured, volcanic glass which shows distinctive curving (conchoidal) fracture patterns.

Pebble: A rock fragment, generally ranging between 4 and 50mm in diameter.

Pumice: A light coloured, low density volcanic rock, having similar composition to obsidian. Pumice is formed by the rapid cooling of magma.

Quartz: An important rock-forming mineral composed of crystalline silica. It is frequently found in many rocks, particularly in the more 'acid' (silica-rich) igneous rocks, such as granite.

Rock: A naturally occurring aggregate of one or more minerals.

Sandstone: A sedimentary rock made up of rounded or angular fragments with diameters of .02 to 2mm. Such fragments are likely to be quartz, feldspar and various rock fragments 'cemented' together.

Schist: A more highly metamorphosed rock than gneiss. Schist shows a pronounced parallel alignment of flaky minerals and tends to split along wavy, uneven lines.

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<u>Sedimentary Rock</u>: A rock formed by the accummulation and cementation of sediment which has been transported by wind, water or ice to the despositional site. Some chemical sedimentary rocks may be produced by precipitation.

<u>Scoria</u>: A dark red or black coloured rock, formed from congealed lava which has a high proportion of ferromagnesian minerals.

APPENDIX B - A FURTHER NOTE ON CLASSIFICATION

The igneous rocks might be further divided into plutonic rocks, i.e. where magma cools very slowly, at depth; pyroclastic rocks, i.e. where material is ejected explosively from a volcano; volcanic rocks, i.e. where lava cools rapidly on leaving a volcano:

IGNEOUS ROCK	PLUTONIC ROCK	PYROCLASTIC ROCK	VOLCANIC ROCK
granite →	granite		
ignimbrite →		ignimbrite	
obsidian →			obsidian
pumice →		pumice	
scoria →		scoria	

The sedimentary rocks could be further classified on the basis of particle size and composition whilst the metamorphic rocks could be subdivided again, on the basis of their degree of metamorphosis.

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