Weizmann Institute of Science
Israel 76100Rehovot,
The Science Teaching Department
The Earth and Environmental Sciences group

Earth systems Workshop

The Rocks cycle

And

The earth systems

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Chapter 1

We are starting a unit about the Earth. What do you think is important for you to know about the Earth?

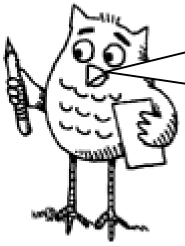
Activity 1-
What is important to know about the Earth?

1. Write down in the left column of the table below 6-10 questions that interest you about the Earth.
2. Sit with your group and add to the second (from left) column those questions that were only mentioned by the other members of the group.
3. Discuss the questions with your friends and decide on 8-10 questions that you all agree are most interesting to know and write them in the third column.
4. Select with your group 5 questions that you all agree that are most important to know and write them in the right column.

What interests me?	What interests others?	The most interesting to all of us?	The most important to all of us?

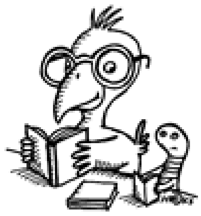
Activity 2- What does the Earth consist of?

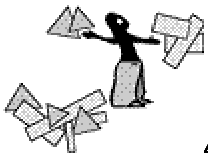
1. Go out to the schoolyard and pick at least 10 specimens that are Earth materials.
2. Go back to the classroom. Characterize and classify the materials that you collected.



Oops, Sorry, I am not sure that you understand the terms Characterization and Classification.
So, let's see together what they mean.

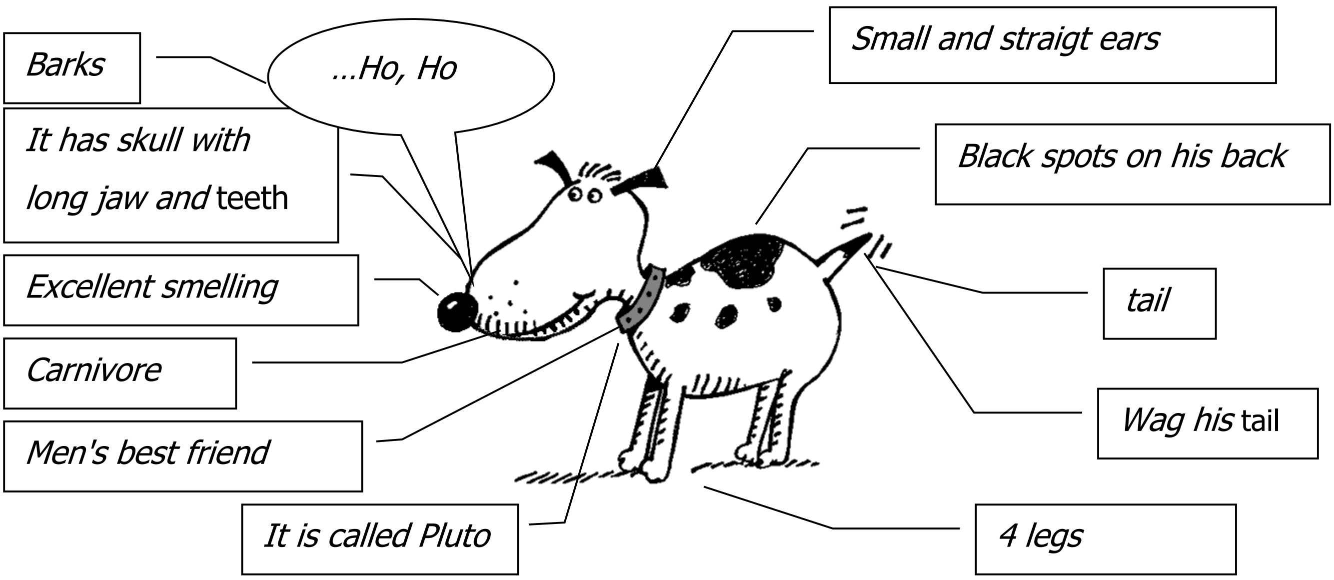
***Characterization**:*
A description of a characteristic that helps us recognize and identify something or somebody.





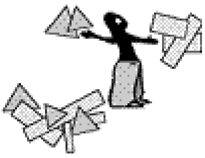
Activity 3- Characterization

1. Please mark the characteristics that ALL dogs have:



2. If you met an animal that you had never seen before, how could you know if it was a dog? ____

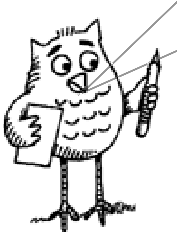
____

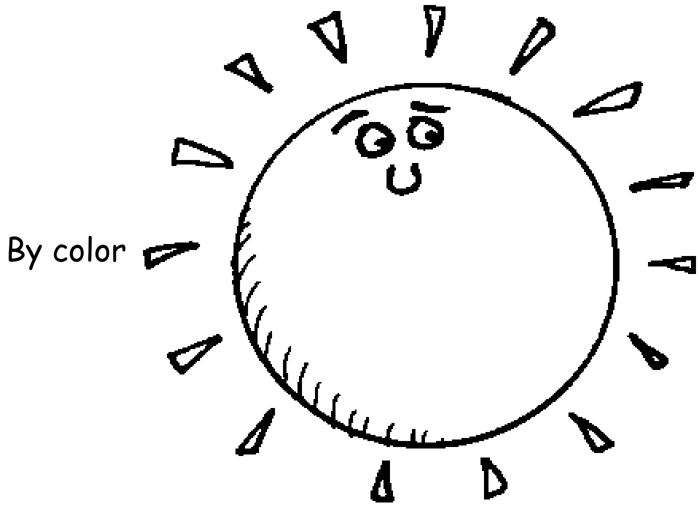


Activity 4 –
Classification of the earth materials that we picked

1. Please, write down all the characteristics you have in mind about earth materials around the circle.

Try to make groups according to the characteristics you observed.





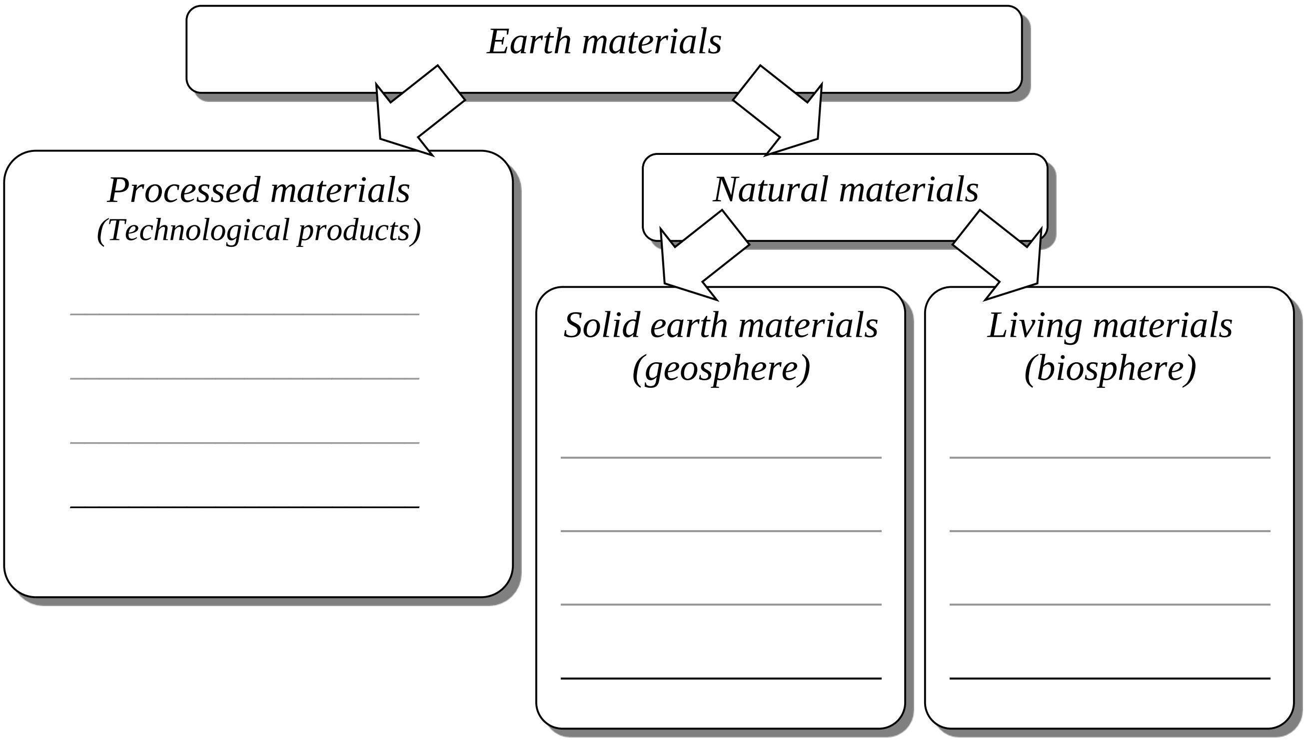
2. Please classify your materials by groups.

Group No.1 *All the items of this group are:* ______________	***Group No.2*** *All the items of this group are:* ______________	***Group No.3*** *All the items of this group are:* ______________

There are many ways to classify materials, and there is no one "right" way.

The chart below presents an additional way to classify the Earth materials.

Please, classify your materials again based on this chart.



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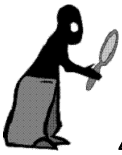
Chapter 2

The characteristics of the Earth materials

In this unit we will learn about materials that build our environment.



Activity 1 - Let's characterize rocks

1. In order to experience rocks' characteristics let's play a "game":
   - There are 8 rocks on the tray in front of you.
   - Play with the rocks and try to feel and sense their characteristics.
   - Select one rock without touching it so that your group members don't know which rock you selected.
   - Take turns describing the rock you have selected to the others in the group. Start with the first characteristic and then, your group members have to find your rock. If they didn't guess right, continue to the next characteristic.
   - The winner is the one who was able to describe the most number of characteristics before his rock was found.

*(**Suggestion**: It is better to start with characteristics which are common to many rocks.)*

2. Write down all the characteristics you used to describe the rocks.

   a. ______________________________________

   b. ______________________________________

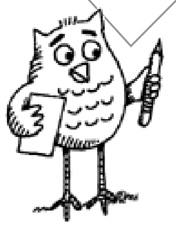
   c. ______________________________________

   d. ______________________________________

   e. ______________________________________

   f. ______________________________________

For example, if the rock that I chose is the smallest among the rocks then the characteristic is "Size".



3. Please, note for each characteristic, if it is a permanent or non-permanent characteristic.

What are permanent or non-permanent characteristics?

Each rock has own characteristics. Parts of the characteristics that you described are permanent and others are not.

For example**, the size of the rock is not a permanent characteristic**. If we break the rock it will become smaller, but it will still be the same rock. Therefore, "Size" is not a good characteristic for rocks' identification since it is not permanent.

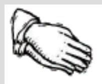
On the other hand, every single part of a specific broken rock will have the same hardness and color. **Therefore, hardness and color are permanent characteristics.**

The permanent characteristics a geologist would use for identifying a rock*

When we want to identify a rock we should only use permanent characteristics which relate to the internal property of the rock and not to its shape or size. Namely, characteristics that will remain the same whenever we test the rock.

Geologists use the following characteristics to identify rocks in the field:

- Color
- Mouldability
- Reaction to diluted chloric acid
- Brittleness
- Hardness
- Taste



In the following activities we will identify rocks by these characteristics.

** A geologist is a scientist who study the world of the rocks*

The area of the earth sciences which deals with studying the solid earth is called geology.

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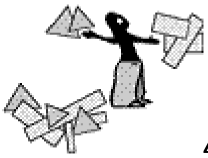
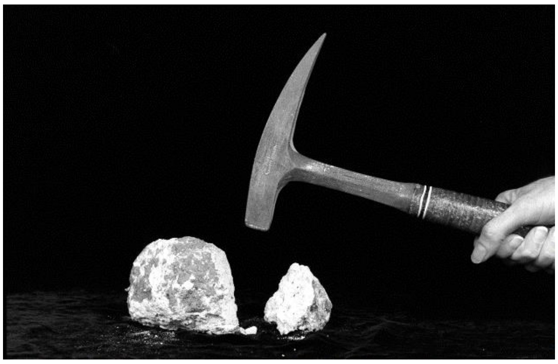


Activity 2 - Classification of rocks by characteristics

How do we test color?

The surface of a rock is exposed to water and air. The interaction with these elements causes the color of the external part of a rock to be darker than its true color. Therefore, in order to test the true color of a rock, we need to break it first and to look at its inside.



1. Please classify the rocks that on the tray by the color. Write in the last column how many rocks you found in the tray for each color group.

The characteristic	*What do we test?*	*Color's classification groups:*	*The number of rocks in each color group (0-8)*
Color	Look at the inner color of the rock and not at the surface color.	1. White	______________
		2. Yellow	______________
		3. Greenish	______________
		4. Red	______________
		5. Brown	______________
		6. Black	1 (One rock)
		7. Other: ___	______________
		8. Few colors together	______________

How we test malleability?

We drop few drops of water on the rock and then massage it with the finger. If you can knead the rock like clay, it means that the rock is malleable.

2. Please classify the rocks that on the tray by the malleability. Write in the last column how many rocks you found in tray for each malleability group.

The catachrestic	***What do we test?***	***Malleability classification groups:***	***The number of rocks in each malleability group (0-8)***
Malleability	We wet our finger with water and rubbed the rock and then we felt if we can knead the rock.	1. Not malleable 2. A bit malleable 3. Very malleable	____________ ____________ ____________

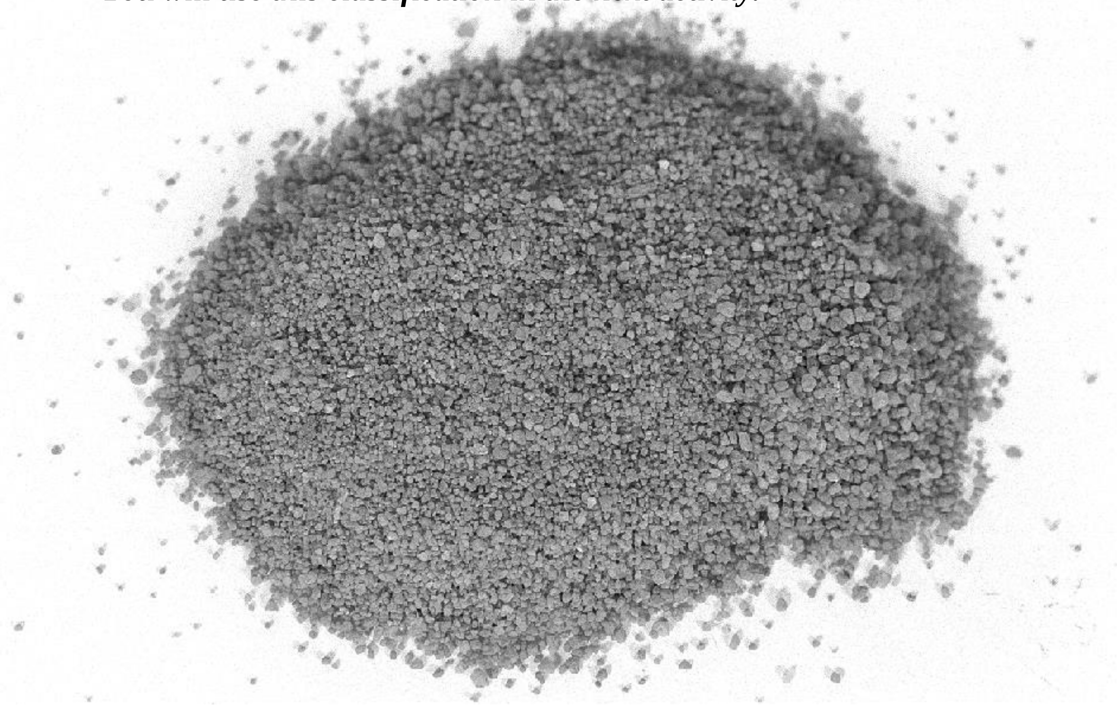
How do we test the brittleness characteristic?

Brittle rocks are rocks that you can crumble with your fingers into grains of sand.
Notice, if the rock crumbles to dust it is not brittle. It is only brittle if you can feel the grains with you fingers.

3. Please classify the rocks that on the tray by their brittleness. Write in the last column how many rocks you found in the tray for each brittleness group.

The catachrestic	*What do we test?*	*Brittleness classification groups:*	*The number of rocks in each brittleness group (0-8)*
Brittleness	We rub or crush the rock with our fingers and try to feel if it crumbles to sand grains.	1. Brittle 2. Non Brittle	____________ ____________

Please leave the rocks as you classified them.
You will use this classification in the next activity.



How do we test the hardness characterisitic?

The hardness characteristic can be tested only with the non-brittle rocks.
We test the hardness of a non-brittle rock by scratching the rock. First we'll try to scratch it with our finger nail and if it is not scratched by the finger nail we try to scratch it with an iron nail.

- If the finger nail will scratch a specific rock, then we conclude that the hardness level of this rock is **soft**.
- If the finger nail won't scratch the rock, we'll try to scratch it with an iron nail.
- If we can scratch the rock with iron, then we conclude that the hardness of this rock is **moderate**.
- But if the iron won't scratch the rock it means that this specific rock is **hard**.

4. Please classify the rocks that on the tray by their hardness. Write in the last column how many rocks you found in tray for each hardness group.

The catachrestic	*What do we test?*	*Hardness classification groups:*	*The number of rocks in each hardness group (0-8)*
Hardness	We ______________ ______________ ______________ ______________.	1. Scratched by nail 2. Was not scratched by nail, but scratched by iron nail. 3. ______________	_________ _________ _________

How do we test the taste?

Before starting this activity, you should wash the non-brittle rocks with water. Then, look for the rock that has salty taste.

5. Test the taste of the non-brittle rocks of the previous activity. How many salty rocks did you identify? ____________

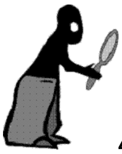
How do we test the reaction of rocks to diluted chloric acid?

In order to see if a specific rock reacts with the acid, we first place one drop of acid on the rock and see what happens. If the rock does not fizz, we might conclude that it doesn't react with the diluted acid. If it fizzes we drop additional drops on the same spot. If it sill fizzes we conclude that this specific rock reacts with this acid.

6. Please classify the rocks that on the tray by their reaction to the diluted chloric acid characteristic.

- Write in the second column the way you test this characteristic;
- In the third column write the classification groups.
- In the last column record how many rocks you found in the tray for each reaction to acid group.

The catachrestic	***What do we test?***	***Reaction to acid classification groups:***	***The number of rocks in each group (0-8)***
Reaction to diluted chloric acid (5%)	We __________ ______________ ______________ ______________.	1. ______________ 2. ______________ 3. ______________	__________ __________ __________



Activity 3 - Identification of rocks

On the tray you will find the rocks that you have identified in the previous activity and identification cards. In this activity we will learn how to use the identification cards for rocks' identification.

1. Select a rock from the tray and characterize it according the table below:

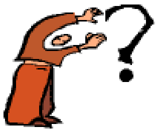
Property	*Characteristic (circle)*
Color	Red / white / gray / yellowish / green / multi colored
Malleability	Malleable / non malleable
Brittleness	Brittle / non brittle
Hardness ***(only for a non-brittle rock)***	Scratched / by nail, Scratched / by iron, not scratched by iron
Reaction to diluted chloric acid	Fizzes / not fizzes

2. The process of a rock's identification
   - Select a rock and take the rocks' card that is on the tray.
   - Follow the stages in the table below. For each stage test the characteristic of the rock.
   - Look at the cards for those that don't have the characteristic that you observed. Eliminate the name of rock from column 3 of the table and put the cards of these rocks aside.
   - After each stage, write down (below the table) the rocks that you eliminated.
   - The last card that is left in your hand should be the card of your rock. Put the rock on the tray and write its name below.

The stages	*Properties*	*Put a line on the rocks that you eliminated in each stage*
A	***Color***	Limestone / Chert / Sandstone / Salt / Granite / Clay
B	***Malleability***	Limestone / Chert / Sandstone / Salt / Granite / Clay
C	***Brittleness***	Limestone / Chert / Sandstone / Salt / Granite / Clay
D	***Hardness***	Limestone / Chert / Sandstone / Salt / Granite / Clay
E	***Reaction acid***	Limestone / Chert / Sandstone / Salt / Granite / Clay

- The rocks I eliminated in stage A (Color): ______________________________
- The rocks I eliminated in stage B (Malleability): _________________________
- The rocks I eliminated in stage C (Brittleness): __________________________
- The rocks I eliminated in stage D (Hardness): ____________________________
- The rocks I eliminated in stage E (Reaction with acid): ___________________

- The name of the rock: ______________________________



Activity 4 – Why do rocks have different characteristics?

In the previous activity we noticed that each rock has its unique collection of characteristics. You probably asked yourselves what is the cause for each characteristic.
In the next activities we will try to find the answers for your question.

A. The taste characteristic

On the tray, you will find the rocks that you already identified and 3 minerals.

> ***What are minerals?***
> In this stage of our learning we will consider minerals as the building blocks of rocks: Minerals are the matter that rocks are built of. There are rocks that are built from only one mineral (uni-mineral rocks) and there are rocks that are built from a few or several minerals (multi-mineral rocks).

Observation

Please taste the three minerals that are on the tray (Don't forget to wash minerals first). Which one of them has a salty taste?

Conclusion

Please use the minerals' identification cards to identify the name of the mineral.
The mineral's name: _______________

Hypothesis

There is a rock that only consists of this mineral. What do you think should be the main characteristic of that rock? __________________

Conclusion

Test the rocks that on the tray. Which rock, do you think, consists of the mineral that you just identified?

> 
> ***Additional information:***
> In order to answer the above question, assume that the mineral that you identify now is the only mineral in the tray that its taste is salty. There are other salty minerals on earth, but they are very rare.

The rock's name: _________

B. *The malleability characteristic*

Observation

Please test the malleability characteristic of the three minerals that on the tray.

Conclusion

Please use the minerals' identification cards to identify the name of the mineral.

The mineral's name: _______________

Hypothesis

There are rocks that consist of this mineral. What do you think should be the main characteristic of such rocks? __________________

Conclusion

Test the rocks that on the tray. Which rocks, do you think, consist of the mineral that you just identified?

> ***Additional information:***
>
> In order to answer the above question, assume that only rocks that consist of the minerals' group that you identified will become malleable with water.

The rocks name: _________, _____________.

Hypothesis

The two rocks that you identified contain the same malleable mineral, but they still appear different. What do you think might cause this variation?

____

C. *The reaction to chloric acid characteristic*

Observation

Which of the three minerals that on the tray fizzes with acid?

Conclusion

Please use the minerals' identification cards to identify the name of the mineral.

The mineral's name: _______________

Hypothesis

There are rocks that consist of this mineral. What do you think should the main characteristic of such rocks? __________________

Conclusion

Test the rocks that on the tray. Which rocks, do you think, consist of the mineral that you just identified?

> ### *Additional information:*
>
> In order to answer the above question, assume that only rocks that consist of the mineral that you identified as fizzing when reacting to diluted chloric acid. There are other mineral that fizz, but they are very rare and the chance you'll meet them is very small.

The rocks name: _________, _____________.

D. *Combination of characteristics*

Observation

1. Which of the rocks that on the tray has two characteristics: malleability and fizzes with acid?

The Rock's name: ________________

Conclusion

2. What might you conclude about the minerals content of this rock (What are the minerals that it consists of)? ________________ , ________________ .

Conclusion

3. Is it a uni-mineral rock or multi-minerals rock? ________________

Conclusion

4. Could you answer now the question that started this activity, namely why we can find various rocks?

____

Observation & *Hypothesis*

5. Look at rock with magnified glass, could you distinguish between the malleable minerals and the fizzing minerals? If not, try to explain why?

____

E. *Exploring the Granite*

Observation

1. In opposite to the marl, which consists of microscopic particles, the mineral crystals of the granite are bigger and visible.

- How many minerals can you notice in the rock (Tip: each mineral has different color)? _______________

Conclusion

2. Is the granite a uni-mineral rock or multi-mineral rock? _______________

Observation & Conclusion

3. Please identify and write in the table the name of the three main minerals that granite is built of. Use the minerals' identification cards.

	Color	***Name***
Mineral 1		
Mineral 2		
Mineral 3		

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Activity 5 – The relationship between characteristics and structure

In the previous activity we noticed that the characteristics of a rock can be derived from the characteristics of the minerals that compose the rock.

In the following activity we will try to find out how the structure of a rock influences its characteristics.

A. The crystalline structure

Observation

1. Among the rocks that you have already identified, you will find a new specimen of polished rock.

- Which of the rocks that you have already identified looks similar to the polished specimen? __________
- Which characteristics are similar in both rocks? ____________________

  ____

Conclusion

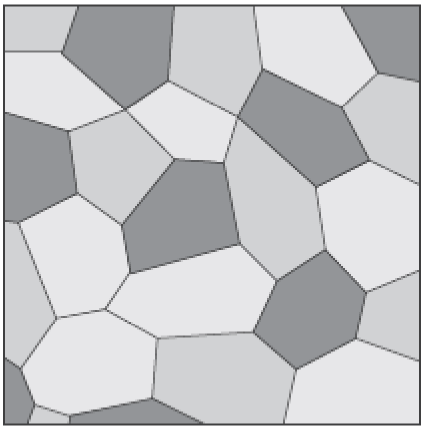
2. Please use the rocks' identification cards to identify the name of the rock.

- The rock's name: ________________

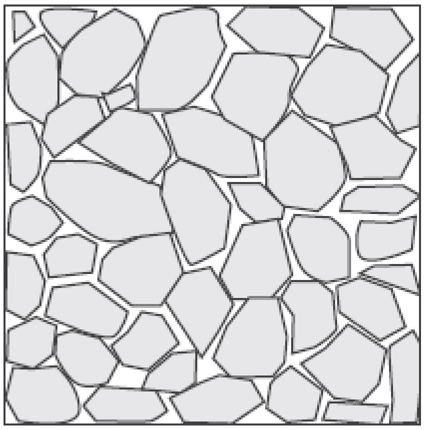
Observation

3. Look at the polished rock. It is easy to notice its internal structure. This structure is called "Crystalline structure". Which of the two illustrations below demonstrates a crystalline structure: __________________?

Structure A



Structure B



B. *The granular structure*

1. Please take the sandstone specimen from the tray.

Observation

2. Look at the sandstone specimen. Even with naked eye it is easy to notice its internal structure. This structure is a "granular structure". Try to look at it under the microscope as well.

- Which of the previous two illustrations demonstrate a granular structure: _____________________?

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C. *A comparison between two different structures of rocks*

Observation

1. On the desk in front of you there are two beakers full of water.

Put the sandstone specimen into one of the beakers.

- Please write down your observations: ______________________________

____

Observation

2. Put the polished granite specimen into the other beaker.

- Please write down your observations: ______________________________

Hypothesis

3. What do you think are the reasons for the different processes you observed in each of the beakers? ____

____

Hypothesis

3. How could you test your hypothesis? ___________________________________

____

Conclusion

5. In the previous activity we concluded that the content of the rocks (the minerals) influences their characteristics. Now, could you suggest another factor that might influence a rock's characteristics?_____________________________

____

Igneous processes – Crystallization experiment

In the previous activities we observed that the rock Granite has a crystalline structure.

The next activity will explore how such rock structure can form in nature.

1. A comparison between Granite and Rhyolite: Why do rocks look different from each other?

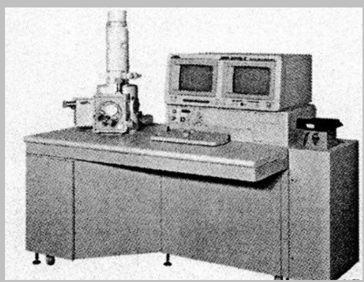
a. Look at the two rocks' samples that in the tray. One sample you should already recognize Gr…. And the name of the second rock is Rhyolite.

- What are the prominent characteristics that distinguish between the two samples?

____

- Could you point any similarity between the two samples? ____________________

Additional (external) information



The chemical laboratory is a very important tool for geologists in the investigation of rocks. Laboratory tests enable to identify the chemical composition (elements and compounds) of the rock. Laboratory tests of the granite and the rhyolite indicate that they both have the same chemical comparison which means that they both are composed of the same minerals.

Hypothesis

b. Try to hypotheses why two samples that consist of the same minerals look so different?

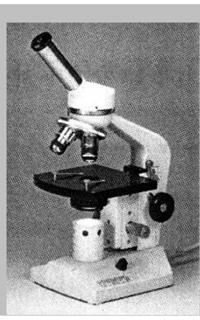
Hypothesis 1: ____

____

Hypothesis 2: ____

____

Another laboratory tool that geologists use to examine rocks is the microscope. The microscope enables to examine a thin slice of rock (0.003 mm) called thin section. The thinness of the thin section allows light to pass through, which allows to observe the internal structure of the rock under a microscope.



Observation

c. Look at the thin sections of the granite and the rhyolite under the microscope. Following your observation what is the internal structure of the rhyolite (circle)?

Granular / Crystalline / Laminar

Observation

d. Try to estimate how much time the crystals of the granite are larger than the crystals of the rhyolite (circle)?

2 times larger / 10 times larger / 50 times larger

Observation **Hypothesis**

e. Is this observation supports your hypothesis why the granite differs from the rhyolite? If so, explain: ____

____

In the next few pages you will find three tasks that summarize the crystallization activity. The tasks relate to the scientific thinking process of drawing conclusions from observations and additional information).

You need to complete one task only.

Summary A – Comparison between Granite and Rhyolite

1. Complete the missing words in the blank spaces below:

In this activity we explored two rocks: __________ and __________. We observed that these rocks look very different, but we have told that lab tests show that they are composed of those of the same _______. So the question arises: Why do they look so different?

When we explored thin sections of the rocks under the microscope we observed that they both have a _________ structure, but the crystals of the ________ are 10 times larger than the crystal of the _________. It seems that the factor that responsible for the different appearance of these two rocks is the size of their ________.

2. Summarize the scientific thinking process that was described in **one** of the above paragraphs, in this order:

Observation A: ____

Additional information: ____

Observation B: ____

Observation C: ____

Hypothesis: ____

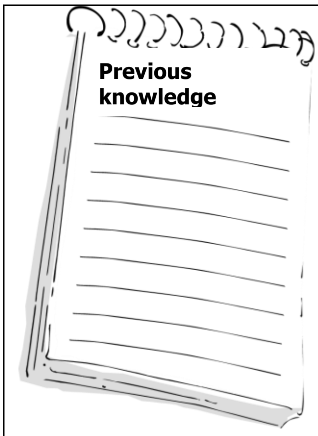
Summary B – Comparison between Granite and Rhyolite

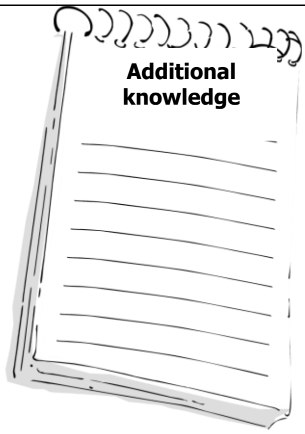
Read the statements below, and for each statement decide if it is: previous knowledge, observation, conclusion, hypothesis or additional information from the activity. (Draw a line to the correct answer)

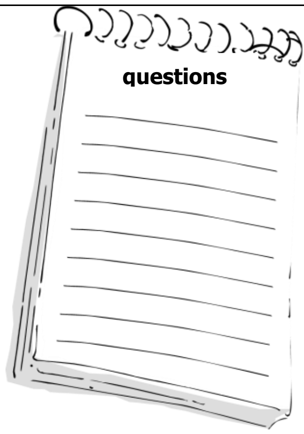
a) The appearance of the granite is very different from the appearance of Rhyolite.		 ***Observation***
b) The granite and the rhyolite are composed of the same minerals.		
c) We saw that the rhyolite is built of microscopic crystals.		 ***Hypothesis***
d) We saw that the granite is built of large crystals.		 ***Conclusion***
e) The difference between the appearance of the granite and the rhyolite rocks arises from the difference in size of their crystals.		 ***Additional information***

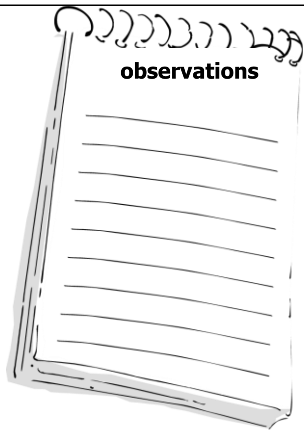
Summary C – Comparison between Granite and Rhyolite

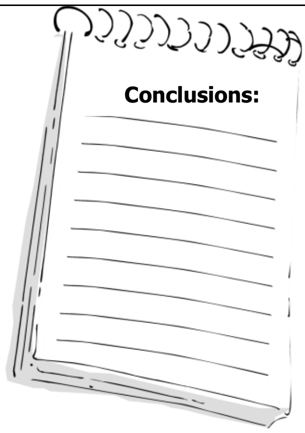
1. Make a list of observations, hypotheses, questions, conclusions, previous knowledge, and additional knowledge which came up during the activity:

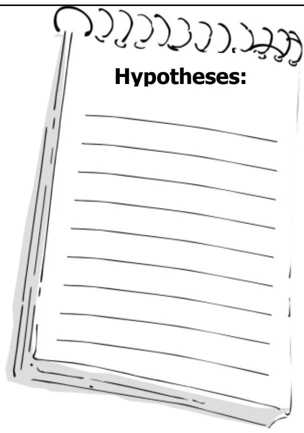




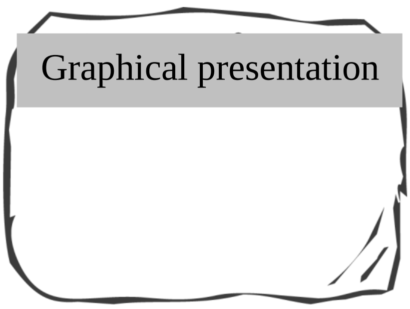


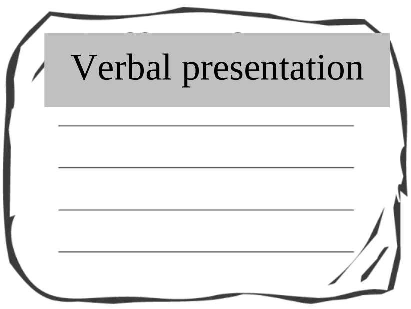






2. Describe in words and/or present in graphics the track of scientific thinking in an activity:



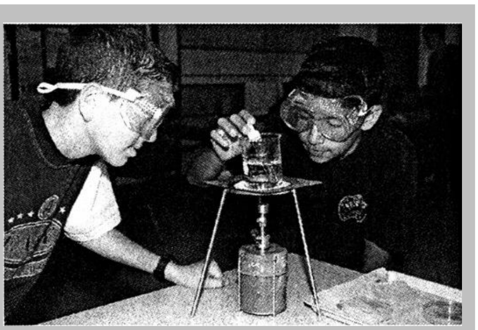


The next activity will help us to answer the question raised following the previous activity: Why often large crystals are formed (like granite) and why often small crystals are formed (as rhyolite)?

2. An experimental simulation

Description of the experiment

We will melt a chemical called Salol (its melting temperature is approximately 50 Celsius degrees). Then, we will cool the melt in two ways: once onto a cold slide and once on a warm slide. We will time the rate of crystals grow on each of the slides, and compare the size of the crystals formed on the slides.



Procedure

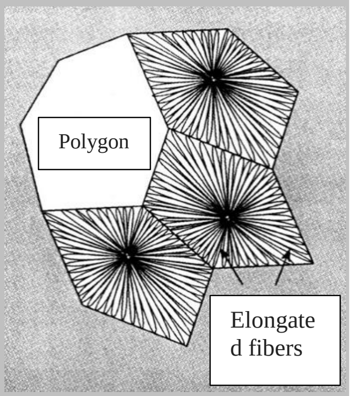
1. Place a slide on an ice pack and make sure it is in a horizontal position.
2. Obtain a beaker filled with hot water on a hot plate. In the beaker, you will have a test tube with a small amount of salol in it. Salol is a chemical that melts at low temperatures.
3. While the Salol is completely melted, carefully place a drop of the melted salol onto the COLD slide and cover it quickly by a thin slide and record the time of crystallization. Write your observation in the table below.
4. Place the tube back in hot water and reheat it.
5. Take another slide and warm it between your hands.
6. Carefully place a drop of the melted Salol onto the WARM slide and cover it quickly by a thin slide and record the time of crystallization while exploring the crystallization process under the Stereoscope.
7. Write your observations in the table below.

Results and conclusions

	Cold slide	Warm slide
Time till crystallization		
Size of crystals		

Assessment of the size of the crystals obtained in the experiment

When the molten Salol cooled and solidifies, crystals are formed.
Solidification generated in crystals is called crystallization.
The crystals of Salol have polygons form that are composed of elongated fibers (see illustration).
To estimate the size of the crystals, note the following characteristics:



1. The size of the Polygons
2. The width of the elongated fiber

As larger is the polygon and / or as the fibers are more width, it means that the crystals of Salol that were formed on the slide are larger.

- What is the process that took place on the cold slide – heating or cooling? Explain:

____

____

- What is the process that took place on the warm slide – heating or cooling? Explain:
(***Hint****: the temperature of the molten Salol is 50 Celsius degrees*)

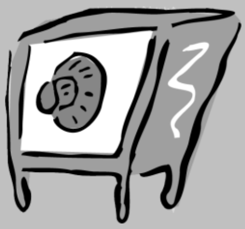
____

____

Summarize your conclusions by completing the following statements from the pool of words below (Please note: the pool includes extra terms):
Large crystals were formed in the process of ____________________________
Small crystals were formed in the process of ____________________________
The factor that determines the size of the crystals is the____________ of _____________

The pool of concepts for completing the statements:

Fast	Rate	Slow
Cooling	Density	Molten
Dissolution	Melting	Heating



In the next few pages you will find three tasks that summarize the simulation activity. The tasks relate to the process of scientific thinking.
You need to complete one task only.

Summary A – Comparison between Granite and Rhyolite

1. Complete the missing words in the blank spaces below:

To answer the question of what determines the size of the crystals in the rocks, we conducted the following experiment:

We melted a substance called Salol and we looked at what happens to him when it cools at different rates.

We observed that the rate of cooling on the warm slide was __________

We observed that the rate of cooling on the cold slide was ___________

When we explored the crystals we observed that _______ crystals were formed on the warm slide, while the crystals that were formed on the cold slide were _________.

Following these observations, we concluded that the size of the crystals depends to the _______ of _____________ of the molten substance.

2. Summarize the scientific thinking process that was described in **one** of the above paragraphs, in this order:

Observation A: ____

Observation B: ____

Observation C: ____

Observation D: ____

Conclusions: ____

This booklet was developed by Prof. Nir Orion and the Earth science group of the Science Teaching Department of the Weizmann Institute of Science.

Summary B – Comparison between Granite and Rhyolite

Read the statements below, and for each statement decide if it is: observation, conclusion, hypothesis or additional information. (Draw a line to the correct answer)

a) Small crystals were formed on the cold slide.		
b) The rate of cooling on the warm slide was slow.		 ***Observation***
c) Large crystals were formed on the warm slide.		 ***Hypothesis***
d) The rate of cooling on the cold slide was fast.		 ***Conclusion***
e) The size of crystals that are formed from crystallization of a molten substance depends on the rate of cooling.		 ***Additional information***

Summary C – Comparison between Granite and Rhyolite

1. Make a list of observations, hypotheses, questions, conclusions, previous knowledge, and additional knowledge which came up during the activity:

Previous knowledge	**Additional knowledge**	**questions**	**observations**
	Conclusions:	**Hypotheses:**	

2. Describe in words and/or present in graphics the track of scientific thinking in an activity:

Graphical presentation

Verbal presentation

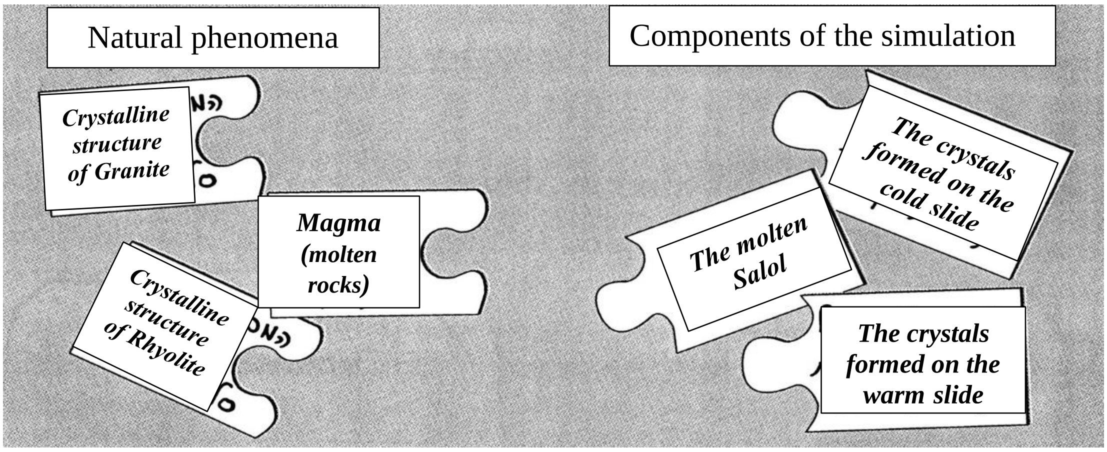
3. What happens in nature?

We have just simulated the formation of the rocks granite and rhyolite.
In the activity below, we will try to relate the simulation to natural processes occurring on Earth.

.

1. Below are two lists. On the right are the components of the experimental simulation and on the left side list of natural phenomena.

- Draw a line between each of the components of the experiment and the phenomenon that it simulates.



2. Now we can answer the questions that triggered the experimental simulation.

- Summarize your conclusions by completing the following statements from the pool of words below (Please note: the pool includes extra terms):

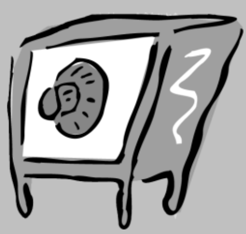
Granite rocks are formed in the process of___________ of ___________ in a ________rate.

Rhyolite rocks are formed in the process of__________ of ___________ in a ________rate.

Crystalline structure of rocks can be formed is a process of __________________________

Concepts' pool for completing the statements:

Slow	Faulting	Pressure
Erosion	Fast	Crystallization
Magma	Folding	Dissolution



4. Where to go from here?

Although we collected a lot of information and developed new knowledge and understanding, we are still left with few open questions such as:

- Where in Earth melting of rocks occurs to form magma?
- Under what conditions magma cools slowly to form granite like large crystals?
- Under what conditions magma cools fast to form rhyolite like small crystals?

Hypothesis

Try to suggest hypotheses about the above open questions. You might verify your hypotheses at the end of the next activity.

Hypothesis 1: ____

____

Hypothesis 2: ____

____

Hypothesis 3: ____

____

In the next few pages you will find three tasks that summarize the last activity. The tasks relate to the process of scientific thinking. **You need to complete one task only.**

Summary A – What happens in nature?

1. Complete the missing words in the blank spaces below:

If we will connect the knowledge we have acquired about the crystals' size of the rhyolite and granite with the conclusions we made following the experiment, we could raise the following hypothesis: The rhyolite, which contains _______crystals is probably a result of a _______ rate crystallization of molten rocks (magma), while the granite, which contains _______ crystals, formed probably at a _______ rate of crystallization of magma.

2. Summarize the scientific thinking process that was described in the above paragraphs, in this order:

Knowledge I already acquired 1: ____

Knowledge I already acquired 2: ____

Hypothesis: ____

Summary B – What happens in nature?

Read the statements below, and for each statement decide if it is: knowledge you already acquired, observation, conclusion, hypothesis or additional information. (Draw a line to the correct answer)

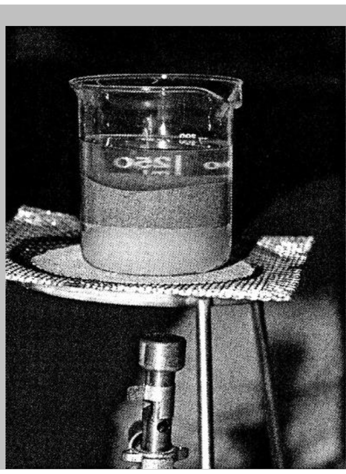
a) Granite is formed as a result of slow crystallization rate of magma.		 ***Observation***
b) Granite consists of large crystals.		 ***Knowledge I already acquired***
c) Rhyolite is formed as a result of fast crystallization rate of magma.		 ***Hypothesis***
d) Rhyolite consists of small crystals.		 ***Conclusion***
e) The size of crystals that are formed from crystallization of a molten rock depends on its rate of cooling.		 ***Additional information***

B. Igneous environments

In the previous simulation we observed that a slow rate crystallization of a melt forms large crystals and fast rate crystallization forms small crystals. Following that we concluded that the rocks granite and rhyolite are formed form melting rocks (magma) that were crystalized by a different cooling rate condition.
In the next activity we will explore where in nature magma could crystalize by different cooling rate conditions.

1. An experimental simulation of an igneous environment

The following beaker includes three materials: sand, wax and water. These three layers represents (simulates) an imaginary cross section in some area of the earth's crust from about 30 km to the surface. It is important to note that the water simulating a layer of solid rock, which by using a "magic goggles" we were able to make it transparent. The transparency will allow us to observe the processes taking place below the surface, within the earth's crust.



Observation

Place the flame under the brim of the beaker (**not** below the center). Carefully light the flame and follow the processes occurring in the glass.
- Describe your observations (note: changes are not immediate, but after a few minutes they will occur at once).

b) From observations to hypothesis

Observation

1. Which of the materials in the beaker changed its physical state? Write down the name of the material and its initial and final states? ___________________________

____

Hypothesis

2. What caused the change of the physical state of the wax? ____________________

____

Hypothesis

3. Why do you think, the melted came go up? ________________________________

Hypothesis

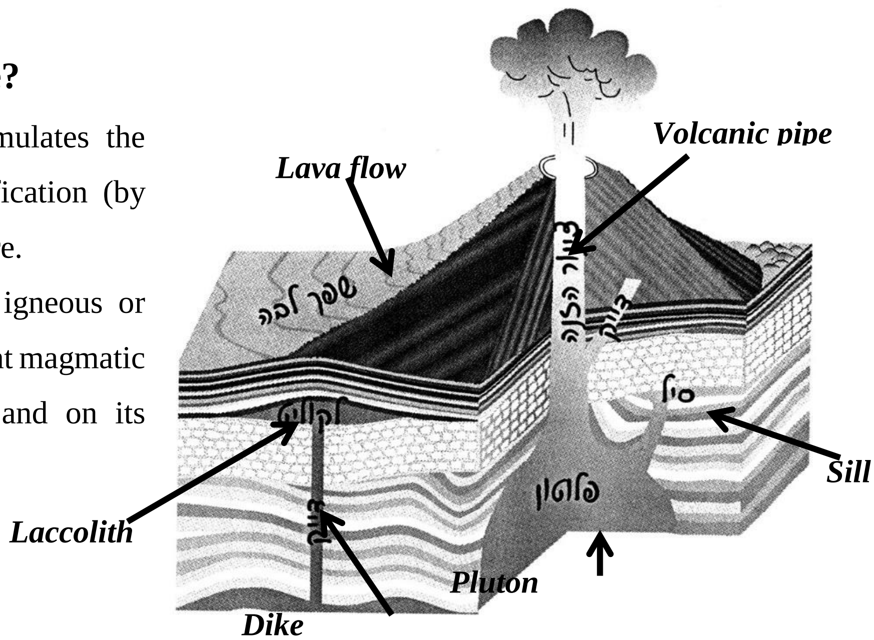
4. Why do you think, caused the solidification of the melt after coming up? _______

____

C) What happens in nature?

The last you just conducted simulates the processes of melting and solidification (by crystallization) of magma in nature.

These processes that are called igneous or magmatic processes, form different magmatic bodies within the earth's crust and on its surface (see figure).

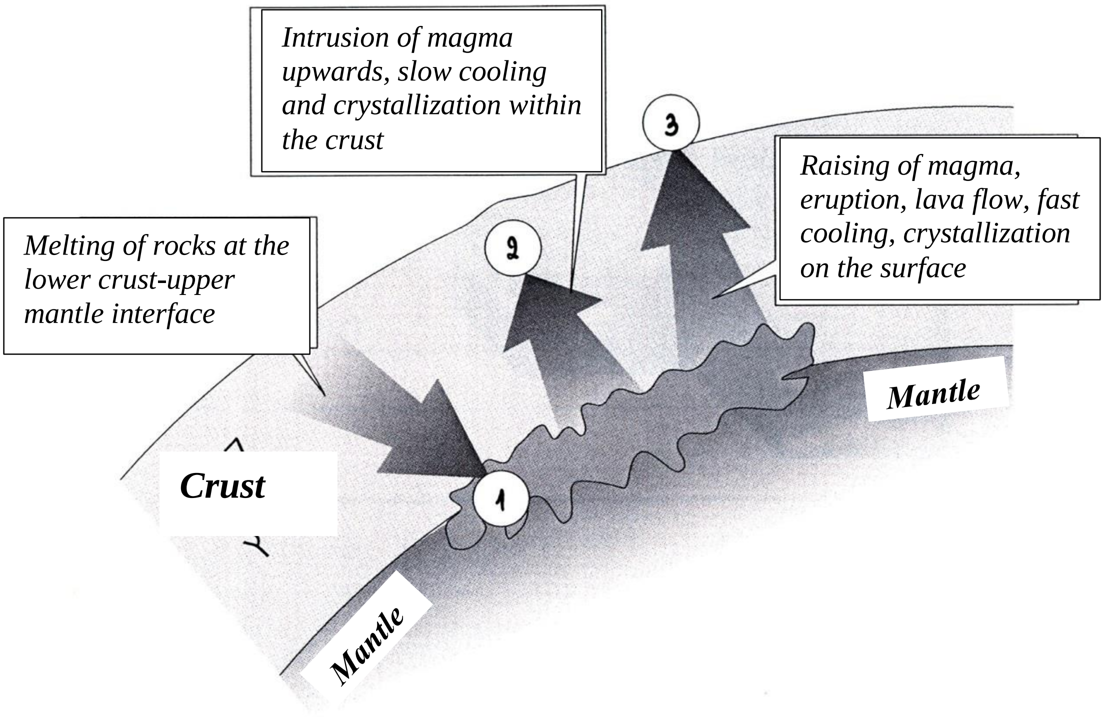


Observation

1. Which of the igneous (magmatic) bodies from the list below is demonstrated by your simulation?

Magma	Dike (vertical intrusion of magma, crossing layers)	Pluton
Volcano	Sill (horizontal intrusion of magma between layers)	Lava flow

2. The illustration below represents part of the Earth's crust and upper mantle. The three arrows there represent the igneous processes that were demonstrated by the experimental simulation. Write down, in each of the rectangles, the name of the igneous bodies that are formed by these processes (use the list of the previous section).



Process 2	Process 2	Process 3

d) How it relates to what we had learned?

Hypothesis

1. Following the last activity, could you suggest, where the granite is formed in nature and where the rhyolite?

Hint: The temperature at a depth of the earth's crust is in a magnitude of hundreds of degrees Celsius.

____

____

Additional information & Conclusion

2. Rocks that are formed by slow cooling and solidification of magma within the earth's crust called ***plutonic rocks*** and rocks that are formed by fast cooling and solidification of magma above the crust called ***volcanic rocks***.

- How, then, would call the granite and the rhyolite (circle)?

Granite is *plutonic/volcanic* rock.

Rhyolite is *plutonic/volcanic* rock.

***How would you call these two rocks*? ___________** rocks.

Hint: *What is the common source for both them?*

The origin of terms "plutonic and "volcanic"

The terms "Plutonic" and "Volcanic" were taken from Roman mythology. Pluto is the God of the underworld (Hell). His name represents the rocks being formed deep in the earth. Vulcan is the God of fire. His name represents the rocks erupting in volcanoes and crystallized on the earth's surface. Granite is an example of a plutonic rock and rhyolite is an example of a volcanic rock.

Basalt - a very common volcanic rock

Basalt is another representative of the volcanic sub-group. Like the rhyolite it is formed by the volcanic process (eruption and rapid cooling of magma) and therefore is composed of microscopic crystals. The difference between these volcanic rocks is their chemical composition (minerals), resulting from the different composition of the magma that created them.

The Igneous (magmatic) group of rocks

The plutonic and volcanic rocks are sub groups of the igneous (magmatic) group which is one of the three groups of rocks that build the crust of the earth (metamorphic, igneous and sedimentary). The igneous rocks are formed by solidification of magma.

e) Where to go from here

In this activity we concluded that granite is formed within the deeper part of the earth's crust. Nevertheless, there are a lot of granite exposures on the earth's surface. So, the question is how rocks, which crystallized and solidified at a great depth could, reach the surface?

Write down your hypotheses about the unresolved question above.
You might check your assumptions during your further Earth sciences studies.

.1 ____

.2 ____

.3 ____

In the next few pages you will find two tasks that summarize the last activity.

Summary A – Simulation of igneous processes and environments

1. Complete the missing words in the blank spaces below:

There is a great temperature difference between the temperature of erupted magma in volcanoes (lava) and the surface temperature (about 1,000 degrees Celsius). Thus, we would expect that erupted lava will solidify at a _______ rate, and that the rocks that are formed there (volcanic rock) will have a very _______ crystals size. Since rhyolite and basalt consist of very _______ crystals size, we can assume that they are _______ rocks (formed on the surface from solidified lava).

There is a small temperature difference between the temperature of magma solidified at depth and the temperature of the rocks at the depth of the earth's crust (about 200-300°C). Thus, we would expect that magma at the depth of the earth's crust will solidify at a _______ rate, and that the rocks that are formed there (plutonic rocks) will have _______ crystals sized. Since granite consists of very _______ crystals size, we can assume that it is _______ rocks (formed at the depth of the earth).

2. Summarize the scientific thinking process that was described in the above paragraphs, in this order:

Additional information: ____

Hypothesis 1: ____

Hypothesis 2: ____

Knowledge I already acquired: ______________________________________

Hypothesis 3: ____

Summary B – Simulation of igneous processes and environments

Read the statements below, and for each statement decide if it is: knowledge you already acquired, observation, conclusion, hypothesis or additional information. (Draw a line to the correct answer)

a) There is large temperature difference (about 1000°C) between the temperature of the magma erupting from a volcano and the temperature of the surface of the earth.		 ***Observation***
b) We might expect that lava erupting from a volcano will solidify very fast.		 ***Knowledge I already acquired***
c) We might expect that the crystals of rocks that are formed from solidification of lava (volcanic rocks) will very small.		 ***Hypothesis***
d) Rhyolite and basalt consist of very small crystals.		 ***Conclusion***
e) It is likely to classify rhyolite and basalt as volcanic rocks.		 ***Additional information***

Erosion Processes – A simulation of mechanical erosion

In the previous chapter we saw how a certain rock is created (Igneous rock). In the following activity we will test what happens to a rock when it is exposed to the external forces which operate on Earth.

A. Comparison between crystals and pebbles

In order to understand the processes that are taking place on Earth, we will try to test natural substances that can be found on the surface. We'll begin with a comparison between a crystal and a pebble, and later on they will be compared with sand.

Observation:

1. These are two samples of natural substances – one in form of a crystal and the other in the form of a pebble. Compare the two samples, and refer to both the mineral composite and the structure. Use the chloric acid, the iron tool and the mineral identification cards.

Properties in comparison	crystal	pebble	Is there a similarity between crystals and pebbles in this property? (write "same" or "different"
Mineral composite (the mineral in the substance)			
The external form of the substance (angular or round)			

You must have realized that the crystal and the pebble are identical in their mineral composite but very different in their form. In the following questions we will try to decipher the reason behind the similarity and the difference between the two substances

This booklet was developed by Prof. Nir Orion and the Earth science group of the Science Teaching Department of the Weizmann Institute of Science.

Hypothesis

2. Try to come up with a hypothesis that explains how substances with similar mineral composite can look completely different from one another. How would you test this hypothesis?

Hypothesis

How to test your hypothesis

____

____

____

____

How can we test our hypothesis? – an example of the scientific thinking process

Very often, the process of scientific inquiry includes a stage of hypothesizing hypotheses following observations done in a lab or in the field. In clauses 2 and 3 we will present an example of a scientific inquiry that comes up from a hypothesis

Hypothesis: Since we found out that the crystal and the pebble have identical mineral composite, it is possible that **one was created from the other.**

Inquiry questions that come up from this hypothesis:

1) Which one of the samples (crystal or pebble) appears now in the original form? Meaning, was the crystal made of a pebble or was the pebble made of a crystal?

2) What is the process that made one substance change its form?

Testing the hypothesis by way of elimination, using acquired knowledge:

We will try to test the hypothesis that we raised – by elimination - following our hypothesis regarding the two possibilities by which the two samples we checked were created: was the crystal made of a pebble or was the pebble made of a crystal.

If we find out the one possibility is wrong, we can continue and test the other possibility.

We begin by testing the possibility that a crystal is made of a pebble.

In the following activity we will check this possibility using knowledge that we have already acquired in previous activities.

Connecting with previous activities

3) The crystal in front of you is relatively big. Can you recall another rock that we know that is built of large quartz crystals?

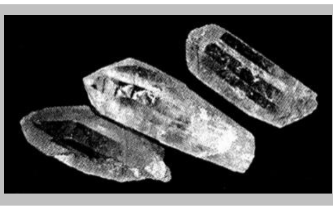
Leaf back in the workbook, refresh your memory, and complete the following sentences:

The rock that we know that has large crystals including quartz crystals is: _________

The natural process that creates such rocks is: ____________________________

We demonstrated this process by the experiment: _________________________

In this process the rock with the large crystals was made from: ________________



Quartz crystals are made in nature by igneous processes. Meaning, if you encounter a large quartz crystal, there is a high probability that it is the product of slow cooling magma.

Now we can eliminate the possibility that the crystal was made from_____________

Therefore, we have to check the possibility that the ______________________ was made of ______________________________

Hypothesis

4. Which process, in your opinion, is responsible for the transformation in the original form of the substance? Where in nature would you expect that such a process will take place? How would you test this hypothesis?

Hypothesis	How to test your hypothesis?
	____________________ ____________________ ____________________ ____________________

We raised many hypotheses regarding the creation of pebbles. It is time to test them. We will do it with an experiment (part 2), but first we will summarize the process of scientific thinking in which we compared crystals with pebbles.

In the next few pages you will find three tasks that summarize the comparison between crystals and pebbles. All the tasks relate to the process of scientific thinking in the activity (drawing conclusions, from observations and additional information).
You need to complete one task only.

Summary A – Comparison between Crystals and Pebbles

1. Complete the missing words in the blank spaces below:

We saw that the crystal and the pebble ________________ in their mineral composite but _________________ in their external form, therefore, we assumed that one sample (either the crystal or the pebble) was created as a result of some process that acted on the second sample.

Thus, the question is which of the samples appears in its original form, and what process caused it to change its form and resemble to the other sample?

At this stage we remembered that we are already familiar with a crystal rock that has a quartz crystal from ___________ of magma. We were also told that this process is the most common process of crystal creation in nature. Following this information, we decided to continue to inquire the second possibility – the one that suggest that the ____________ pattern is the result of some process that operated on the _______________ pattern (and not the opposite).

2. Summarize the scientific thinking process that was described in **one** of the above paragraphs, in this order:

Observation A: ____

Observation B: ____

Hypothesis: ____

Research question: ____

Previous knowledge: ____

Additional information: ____

Hypothesis: ____

Summary B – Comparison between Crystals and Pebbles

Read the statements below, and for each statement decide if it is: previous knowledge, observation, conclusion, hypothesis or additional information from the activity. (Draw a line to the correct answer)

f) The crystal and the pebble are very different from one another. g) When we tested the crystal, we found the following characteristics: not malleable, not fizzes with acid, not scratched by iron. h) The crystal and the pebble we tested have similar mineral composition – they are made of quartz. i) One of the samples (the crystal or the pebble) is created by some process that has operated on the other sample. j) The crystallization of magma is the most common process that forms quartz crystals in nature. k) The quartz pebble is formed by some process that has operated on the quartz crystal (and not the other way around).		 ***Previous knowledge***  ***Observation***  ***Hypothesis***  ***Conclusion***  ***Additional information***

Summary C – Comparison between Crystals and Pebbles

1. Make a list of observations, hypotheses, questions, conclusions, previous knowledge, and additional knowledge which came up during the activity (see an example on page 27 in unit 2 "substances"):

Previous knowledge	Additional knowledge	questions	observations
	Conclusions:	Hypotheses:	

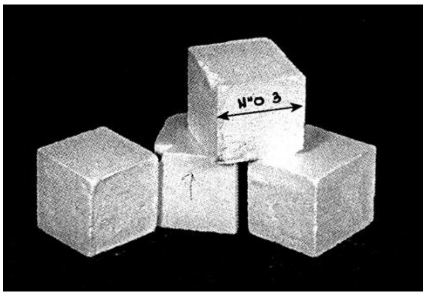
2. Describe in words and/or present in graphics the track of scientific thinking in an activity (see an example on page 27 in unit 2 "substances"):

Graphical presentation	Verbal presentation

B. An experimental simulation of mechanical erosion

In this experiment we will see what happens to four plaster cubes when shaken from side to side in a plastic pipe. We will examine the change that has occurred in the shape and mass of the cubes as a result of the act of shaking.

Procedure



1. Take a cube and draw an arrow on one of its sides.
2. Put the marked cube on square o (next page) so that the arrow will point up, and draw the exact shape of the cube's side.
3. Measure the mass of the four cubes using scales.
   The mass of the four cubes is _____ grams.

4. Put the cubes inside the pipe, shake them by tilting them 50 times from side to side (see picture).
5. Calculate the distance that the cubes did in the pipe (multiplication of the length of the cylinder with the number of shakings), according to this:
   distance of transportation after one shaking:
   1 x (length of cylinder) = __________ centimeters
   Distance of movement after 50 shakings:
   50 x (length of cylinder) = ________ cm = ____ meters
6. Take the cubes out from the cylinder; find the cube that was marked with an arrow, and draw again its exact shape in square 1 (see below), when the arrow points up.
7. Shake the cubes additional 50 times and draw the shape of the cube with the arrow in square 2.
8. Continue to examine the changes that occur in the shape of the cubes while shaking them in the cylinder from side to side, and draw the shape of the cube with the arrow after 50 times in square 3, 4 and 5. After 250 shakings, measure again the mass of the four cubes.
   The mass of the four cubes is _____________ grams.

This booklet was developed by Prof. Nir Orion and the Earth science group of the Science Teaching Department of the Weizmann Institute of Science.

Drawing of cube After 100 shakings 2	Drawing of cube After 50 shakings 1	Drawing of original cube 0
Drawing of cube After 250 shakings 5	Drawing of cube After 200 shakings 4	Drawing of cube After 150 shakings 3

C. Assembling the results of the experiment

1. Summarize your observations in the table on the next page.

Please note that there is a column in the table for writing the extent of roundness of the cubes. In order to decide this parameters, ask the teacher for a slide of the cubes' scale of roundness.

How to use the slide of the roundness scale?

Put the slide of scale of roundness on the drawings of cubes that you drew in the previous page.

Since the size of your cube is probably different from the size of the cubes in the slide, examine the roundness by attaching the corner of the first level of roundness in the slide (level 0) to the corner of your drawings, and see if the roundness line is completely congruent. If your drawing is rounder than this sample, try to attach it with the second level of roundness. (level 1). Continue this process till you get the best match between the slide and the drawing.

Important: The only correct results are those that you have from your observations!

Don't try to "modify" your observations with results that seem to be "correct" – there is no such thing!

Number of shakings	Distance of transportation (calculated by the No. of shakings)	Distance of transportation (in meters)	Extent of roundness of the cubes (according to the drawings of the cubes)
0			
50			
100			
150			
200			
250			

This booklet was developed by Prof. Nir Orion and the Earth science group of the Science Teaching Department of the Weizmann Institute of Science.

2. Calculate the mass that the cubes lost as a result of the shakings during the experiment. The mass in the beginning of the experiment minus the mass at the end of the experiment equals the mass the cubes lost.

_________________ - ________________ = grams

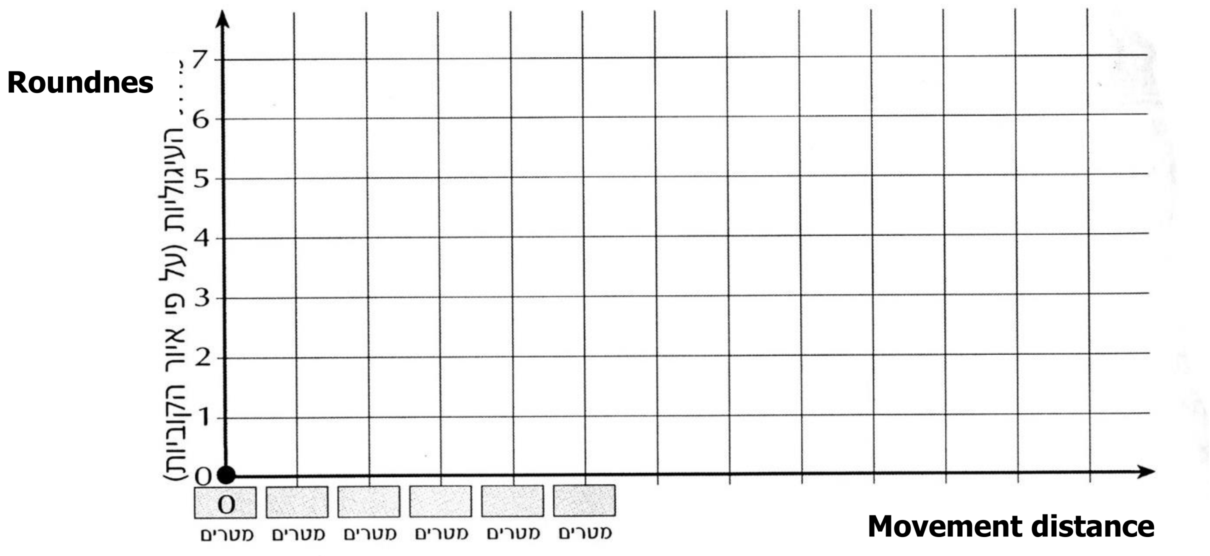
Many times, graphic presentation of the data illustrates better than a presentation in a table. In the next part we will present the data we collected using a graph that describes the dependence between the extent of the roundness of the cubes and their movement distance.

D. Presenting the results of the experiment using a graph

Instructions: How to draw a graph that depicts the change in roundness of the cubes as depending on their movement distance.

1. In the grey squares below, write the movement distance that matches the number of shakings. (For instance – after 0 shakings, the distance is 0 centimeters; Therefore, we wrote 0 in the left hand column).
2. For each parameter of movement distance, make a dot that matches the extent of the roundness of the cubes in that movement distance. (For example, after a movement distance of 0 centimeters, the extent of the roundness was 0; make another dot where the distance and the extent of roundness meet).
3. Connect all the dots with a line.

The influence of the movement distance on the roundness of the cubes



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E. Analysis of the experiment's results

Conclusion

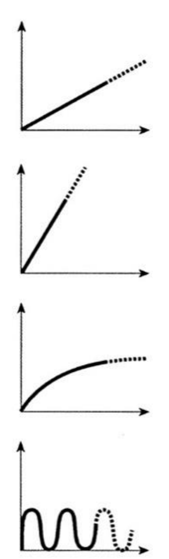
1. Look at the graph that you drew. What is the connection between the extent of roundness and the movement distance? ________________________________

____

2. In your opinion, what is the process that caused the cubes to be rounder?
Write down your hypothesis, and mention the observations on which you based this hypothesis.

The hypothesis	The observation on which it was based
	______________________ ______________________ ______________________

Advanced activity



One of the advantages in presenting data using a graph is in the option to identify the direction the development of experimental data.
If we assume that this direction represents the process we have examined, then we can hypothesize how the rest of the graph would have looked like had we continued to collect data.
On the right there are a few examples: (the experimental graph is in a bold line, whereas the hypothesized part is in a broken line).
The hypothesis regarding the continuation of the graph provides us with a tool to predict. In our example, for instance, we can assess the movement distance where the cubes will be completely rounded. (level 7). Let's do it following these instructions:

Questions and instructions how to draw the rest of the graph:

- Look at the graph you drew (page 50). Try to identify a general trend in the data (general development direction of the corrosion in the cubes).
- Try to present possible continuation to the rounding process of the cubes using a broken line that continues the line you have drawn.
- Can this line rise indefinitely? If not, what limits it? (clue, can the roundness level exceed 7?)
- How will the graph continue once it hits roundness level 7? (continue or correct the line you drew).

Predicting phenomena using the continuation of the graph:

- According to the graph you drew, what is the movement distance needed to turn cubes into completely round "pebbles" (level 7)? ____________________meters

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F. What happens in nature? Simulation and reality

The experiment we have just performed simulates the formation of one of the samples that we examined when we started this activity – the crystal and the pebble.
We will return to these samples and try to see the connection between the simulation with the processes occurring in earth.

Conclusion

1. Below you will find two lists – one of the components of the simulation experiment, the other list is of the natural phenomena the experiments simulate. Draw a line between each component of the experiment and the natural phenomenon it simulates.

Natural phenomenon	Components of simulation experiment
☐ Stream	☐ Plaster cubes at the starting point
☐ Crystals or rock pieces	☐ Plaster cubes during the experiment
☐ Pebbles	☐ Creating a slop in the cylinder to cause the cubes to roll
☐ Mechanical erosion of rocks by the stream	☐ The cylinder
☐ Creating height topography relief by internal forces (folding and faulting)	☐ Shaking the cubes in the cylinder

Conclusion

2. What can you conclude from the experiment considering the way the pebble you examined, was formed? ____

____

Hypothesis

3. In what part of the stream would you expect to find a pebble similar to the pebble you examined? Upstream, in the middle or near the estuary? Explain: ____________________

____

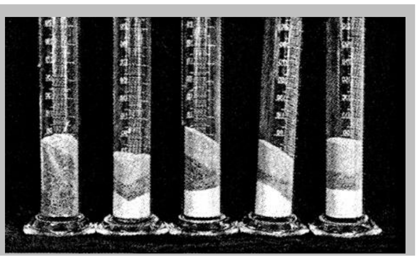
Food for Thought:
We learned that pebbles are formed as a result of eroding one another while moving in a stream. We know that streams are formed in places with height differences, when gravity causes water to flow from higher places to lower places.
In your opinion, what process causes the height differences?
As we continue, in the unit "The transformation of solid material from the inner to the surface of earth" we will try to answer this question.

Sedimentation processes – A modeling experiment of sedimentation in a still water environment

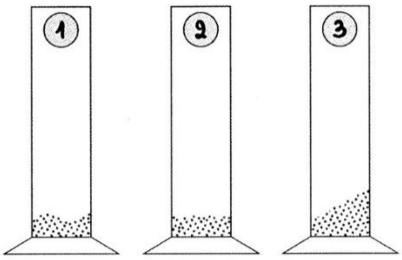
In the previous chapter we realized that rock fragments may undergo a process of a mechanical erosion. While transporting them in streams of water.
In this chapter we will see what happens to rock particles when they reach a quiet watery environment (without currents).

A. The basic principles of sedimentation processes

In order to get to know the basic principles of sedimentation processes in stationary water (without currents), we will examine how sand grains are graded in a cylinder filled with water

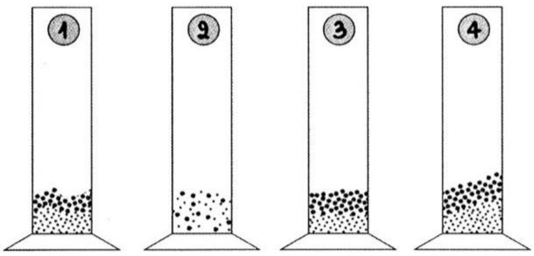


1. What do you think the sand will look like inside the cylinder, when the teacher pours a handful of sand into the water-filled cylinder (circle)?
   Option 1 / Option 2 / Option 3



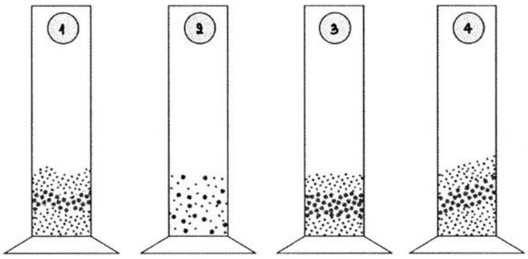
2. The demonstration (circle the right option) *Confirmed / Refuted* my hypothesis.

3. Mark the number of the cylinder below that in your opinion represents the sand structure that will be formed in the cylinder following pouring of the second handful of sand.



4. The demonstration (circle the right option) *Confirmed / Refuted* my hypothesis.

5. Mark the number of the cylinder below that in your opinion represents the sand structure that will be formed in the cylinder following pouring of the second handful of sand.



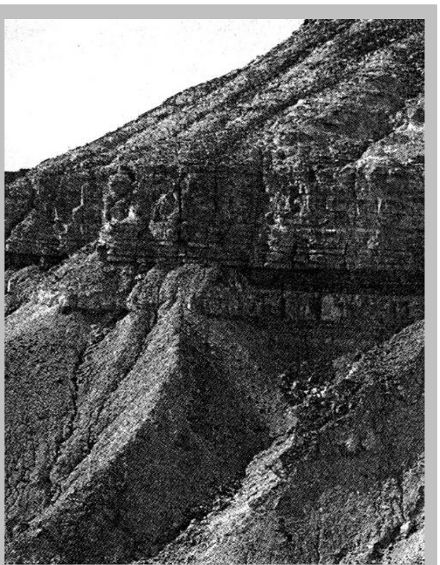
6. The demonstration (circle the right option) *Confirmed / Refuted* my hypothesis.

7. Summarize your observations. Circle the correct sentences among the 4 sentences below:
a) When you pour grains into a cylinder full of water, the new grains mix with the old ones, and they settle on the bottom of the cylinder as a mixture.
b) When you pour grains into a cylinder full of water, they settle on the bottom horizontally.
c) When you pour grains into a water-filled cylinder, they form in layers, with the new layers laid down beneath the old layers.
d) When you pour grains into a water-filled cylinder, they form in layers, with the new layers laid over the old layers.

8. What physical force, in your opinion, caused the grains to settle down on the bottom?

____

Sedimentary rock



The observations you have made on the cylinder represent very important processes occurring in nature on a much larger scale. Gravity causes grains and other natural substances to settle on the earth surface (seas, oceans, lakes, rivers, and exposed areas on land). The settlement of the materials occurs in the form of layers - layer upon layer. The rocks that result from such sedimentation are called sedimentary rocks, one of whose distinguishing features is the layering structure.

The regularity of the stratification in still water bodies

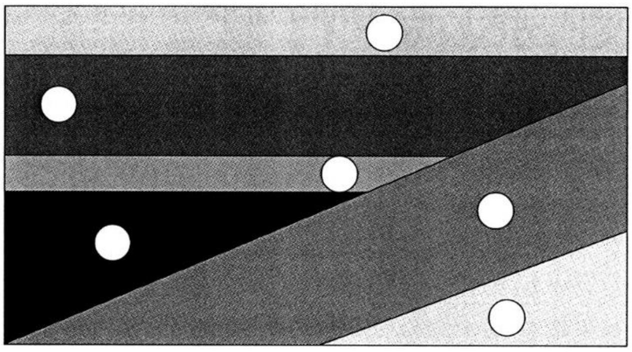
The generalization the cylinder sedimentation demonstrations to natural places of still water bodies (without streams) such as lakes, seas and ocean leads to the development of the following principles of sedimentation:

Principle of the original horizontality: Material that settles on the bottom of a still water body, deposited in horizontal layers.

The Superposition principle: In a series of layers of sedimentary rocks, each layer is younger than the layer below it, and older than the layer above it.

8. The drawing below represents a cross section of different rocks layers. Each rock is represented by a different shade of color.

- Answer the following questions on the assumption that all layers are composed of marine sedimentary rocks that were sedimented in a still water body, without currents.



A) Are all the layers shown in the drawing above are in their original state of deposition (circled)? *Yes / No*

B) What principle established the basis for your previous answer? ____________________

____

C) If you circled "No" in question A, answer the following question:

- What processes, in your opinion, could have caused a change in the original position of some of the layers? ____

D) Mark on the circles that are on the layers, the order of formation (mark the oldest layer at 1, the next one at 2, and continue to layer 6).

E) What principle established the basis for your order of the layers by time of formation? ____

F) Try to describe the geological history of the area. Use the following guiding questions: How were the first two layers laid down? What process took place after their loss? What happened when this process stopped working?

____

____

____

Where do we go from here?

In this activity we have seen that sedimentary rocks are matter and depositing it in layers on Earth. In the next activity we meet some of the materials that are depositing on the bottom of the ocean.

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Interrelationships between the Geosphere and the Biosphere: Deciphering formation environments of sedimentary rocks

In a previous chapter we saw that grainy structure sedimentary rocks such as sandstone.
In this chapter we will introduce additional sedimentary rocks.
Based on observations of the rocks and their components, we will attempt to decipher where and how they were created.

1. On your tray you should find three items**:**
- polished rock,
- fossils,
- shells taken from the beach

1. Identify polished rock that on the tray (Use ID cards).

Rock Name: ____________

The mineral from which this rock is built is ____________

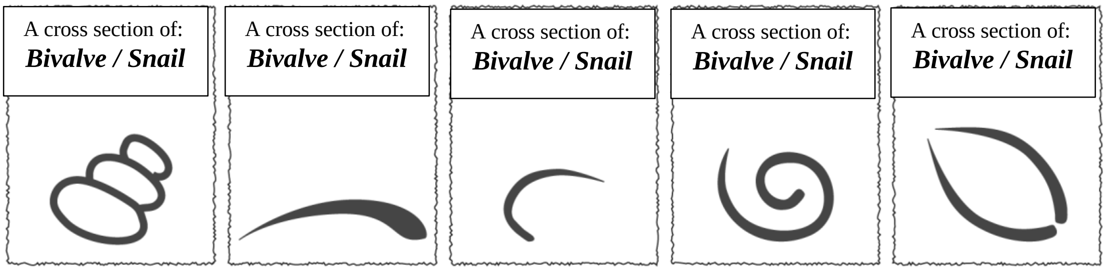
We reached this conclusion based on the following observations: _______________
____

The polished rock sample includes fossils of marine bivalves and snails, but when the rock was sawed the fossils that were inside the rock were also cut and crossed, so it is a bit difficult to identify them.

In the activity on the next page you will get instructions to help you identify these fossils.

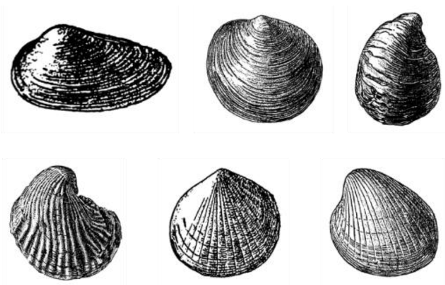
2. Below are schematic cross sections that can be made when sawing a rock that includes fossils of bivalves and snails. Use the illustrations to determine the type of fossil that each cross section represents.
(Circle each type of fossil: "*bivalve*" or "*snail*").

Hint: In order to accomplish this task, it might be useful to conduct the next pages' activity "***Demonstration of bivalves and snails' cross-sections using plasticine models***"

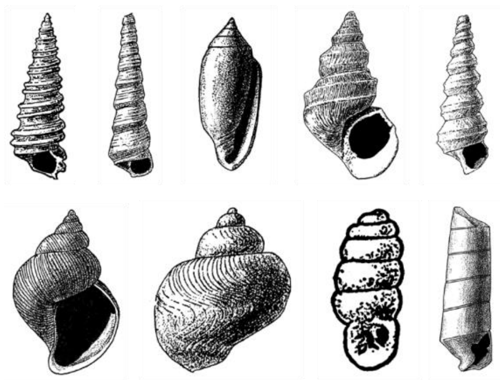


3. Look at the polished rock again and circle below the fossils that you recognize?

Bivalve fossils



Snail fossils

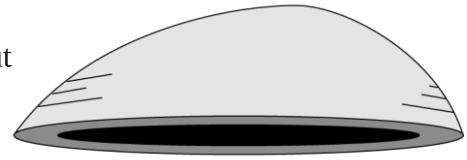


Common bivalve and snail fossils (the size of each fossil in reality is 2-3 cm):

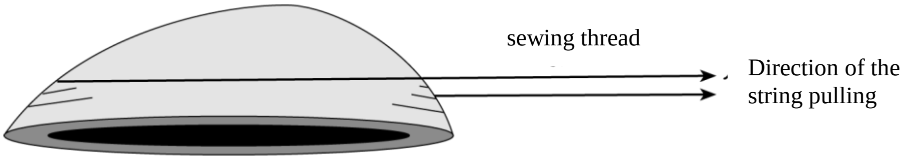
Demonstration of bivalves and snail's cross-sections using plasticine models

1. Take a small piece of plasticine (a sphere about 2cm in diameter) and create a model of a bivalve similar to the drawing below:

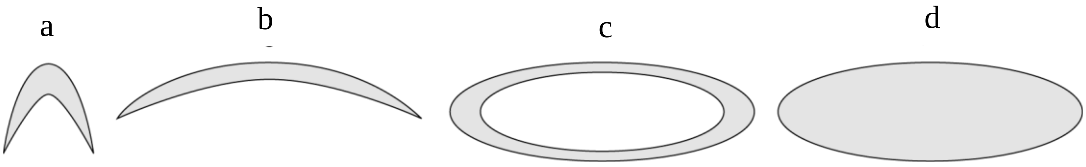
Leave the walls thick enough to cut the model without destroying its shape (about 0.5cm thick)



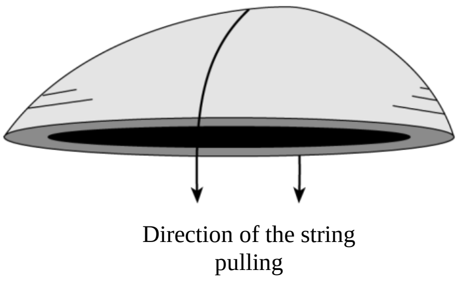
2. Cut the bivalve model by the sewing thread as shown in the drawing below:



- Remove the top (cap) that was obtained after the cut.
  Which of the cuts below is similar to the resulting cut? ((a / b / c / d).



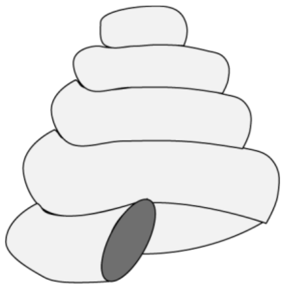
3. Now cut the bivalve model by the sewing thread perpendicularly as shown in the drawing below:



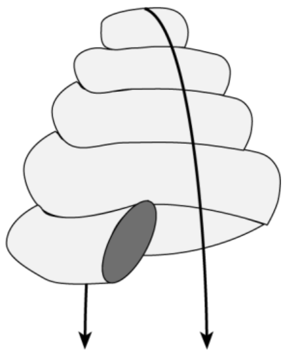
- Which of the cuts above is similar to the resulting cut? (a / b / c / d).

4. Take a larger amount of plasticine (about 3cm in diameter) and create an elongated cone (about 4cm) that resembles the following illustration:

5. Roll the cone that you created and create a model of a snail, similar to the following Illustration below:



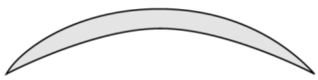
6. Cut the snail by the sewing thread as shown in the drawing below:



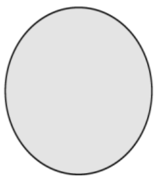
Direction of the string pulling

7. Which of the cuts below is similar to the resulting cut? ((a / b / c / d).

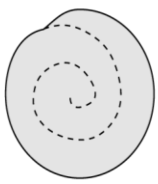
a



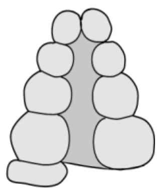
b



c



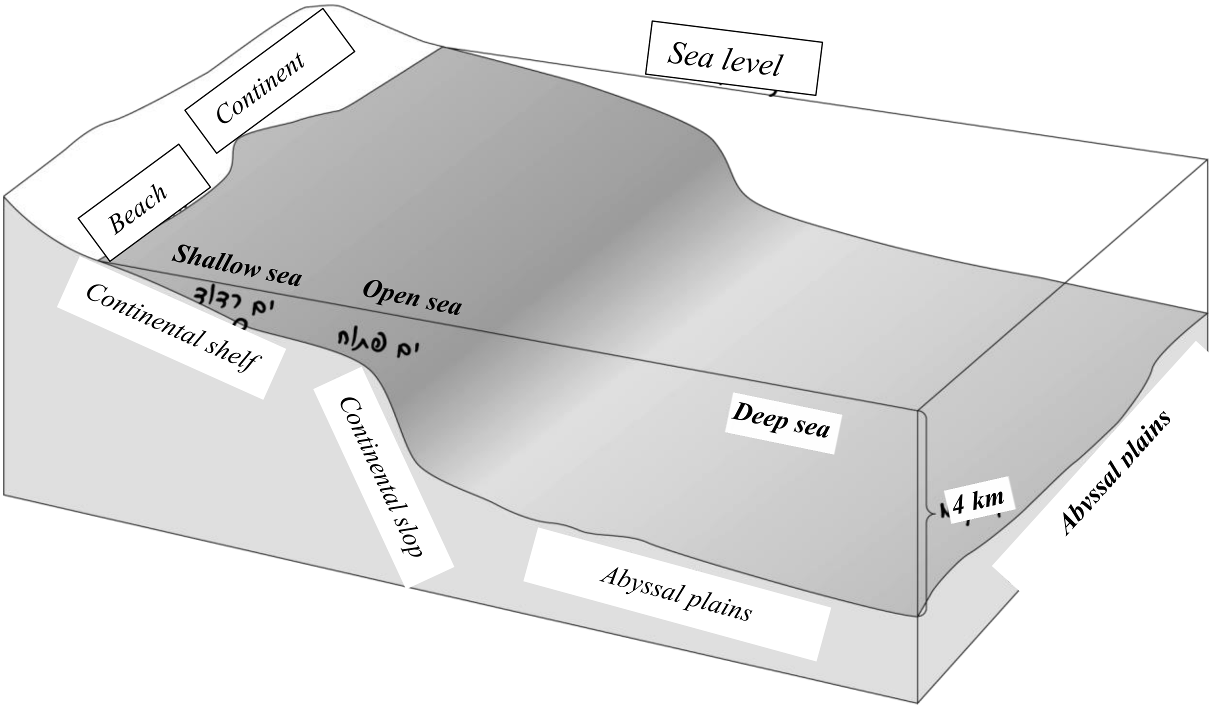
d



4. Animals such as oysters, sea slugs, and sea urchins live today in the tidal regions of the sea, adjacent to a bedrock or coral reef.

Look at the illustration below. In what area of the sea would you expect the shells of these animals to be deposited after their death (circle the correct answer)?

Shallow sea / open sea / deep sea



The principle of "The present is a key to the past"

One of the greatest challenges facing geologists is the reconstruction of processes that occurred millions of years ago. The principle that geologists rely on to understand past processes is the principle of "The present is the key to the past."

The underlying assumption behind this principle is that materials formed in the past were created in the same processes that create such materials today. In other words, the earth operates according to the same "rules" from the earliest periods to the present.

Thus, the method in which past processes can be reconstructed is a comparison to similar or identical processes that occur in the present.

For example, if we can identify fossils in a rock, which are very similar to animals found in today's shallow sea environment, we can conclude that in the past such animals existed in the shallow sea, and therefore the rock appears to have been formed in a shallow sea.

5. What is the **formation environment** of polished rock (circle)?

river / dune / shallow sea / open sea / deep sea

- What is the principle upon which your answer is based: ___________________

  ____

6. You were able to reconstruct the formation environment of limestone by using the principle of "the present is a key to the past".

But you have not yet determined how this rock is formed.

A) According to your observations so far, from where do you think comes the material that builds the limestone? ____________________________________

____

B) From where do you think comes the material that builds the skeleton (shells, bones) of animals? ____

Hint: Water and carbon dioxide decomposes the material that builds up the limestone in a very slow process.
The calcite that builds the limestone dissolves in water reaches the sea.

Material transitions between Earth systems

The illustration below represents material transitions between three of the Earth's systems: The geosphere, the biosphere, and the hydrosphere.

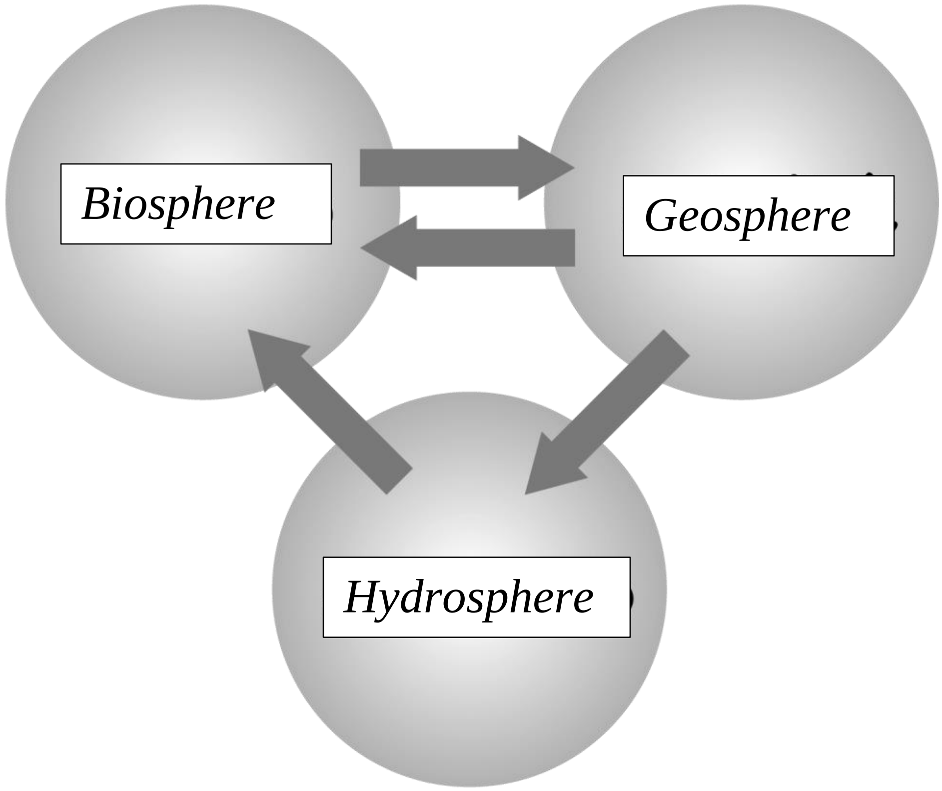
Write on each arrow the number of the sentence describing the passage of the appropriate material, from the following list:

1. Use of minerals in the soil by plants for their growth.

2. Building skeletons (shells / bones / teeth) of aquatic animals from minerals originating from sea water.

3. The accumulation of skeletons of animals on the bottom of the sea, turning them into biogenic rocks such as limestone.

4. The decomposition and dissolution of exposed rocks, and the transport of the products to the sea through streams.



Metamorphic rocks and Metamorphism

Till now we explored two groups of rocks that build the earth's crust: The igneous group and the sedimentary group.
*In this unit we will learn about the **metamorphic rocks** - The third group of rocks that build our crust.*

A. Changes of rocks' structure

Observation

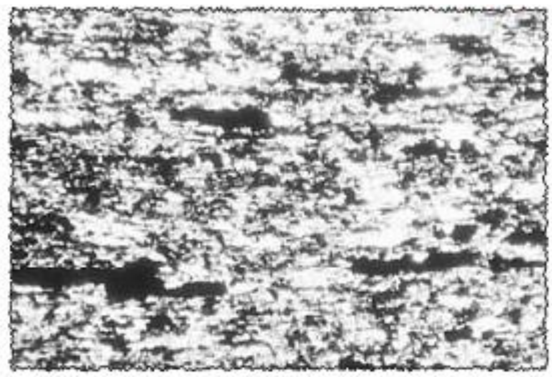
1. Look at the two rocks' samples that in the tray and at the two drawings below which are microphotographs of thin sections (microscopic slices) of these two rocks.

- Could you point any similarity between the two samples? ___________________

Hint: Both samples have a crystalline structure. …Look at their orientation…

*A thin section of rock sample **B** (magnification x 7)*

*A thin section of rock sample **A** (magnification x 7)*



Crystalline rocks that their crystals are oriented in the same direction are called **metamorphic rocks**.
Definitions:
A metamorphic rock of crystals size of tens of a millimeter (medium) is called **Schist**
A metamorphic rock of crystals size bigger than a millimeter (coarse) is called **Gneiss**

Conclusion

2. Rock A is (circle) Schist / Gneiss

Observation

3. Ask the teacher to bring you a sample of rock C and identify it.

- The name of rock C is ________________

4. Compare the Gneiss sample with the additional rock you have just received (rock C).

	Gneiss	Sample C: ________
Color	One color / multi colors	One color / multi colors
Crystals' size	Large / Medium / Small	Large / Medium / Small
Crystals' orientation	Random / uniform (parallel)	Random / uniform (parallel)

Hypothesis

5. Try to hypothesis what is the process that could turn granite to gneiss and where you might expect it to take place? ____

____

Observation

6. On your tray you will find two flat squares of plasticine.

- Spread on each of the flat surfaces grains of rice **randomly**.

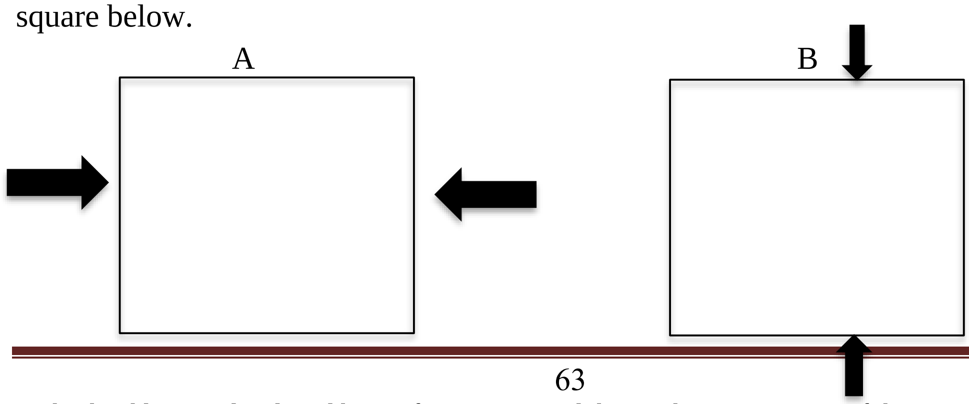
- Place your palms vertically on either sides of the surfaces and press one surface in the direction of the arrows in drawing A (below), and press the second surface in the direction of the arrows in drawing B (below).

- Do you notice a change in the orientation of the rice grains following the pressing?

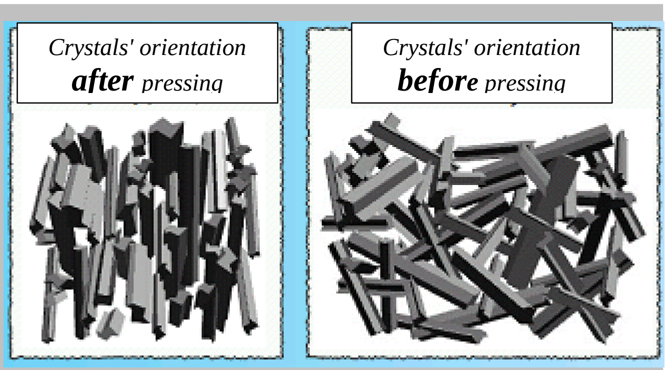
Explain: ____

____

- Draw the orientation of rice grains in each of the compressed surfaces in the suitable square below.

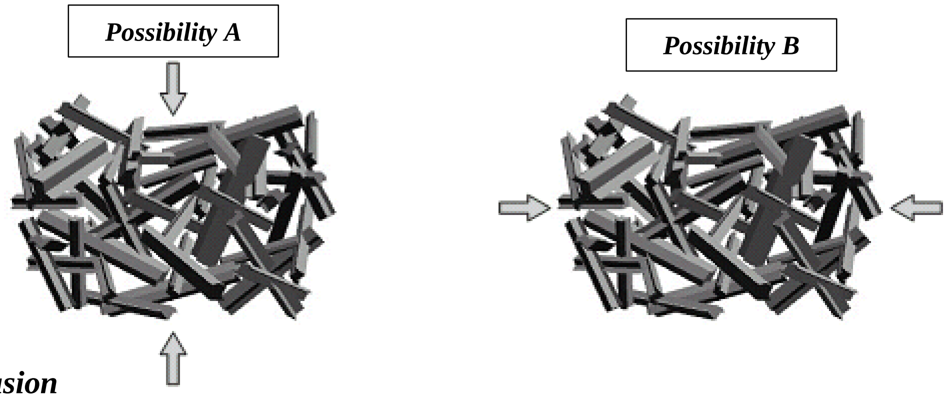


About 150 years ago, a Danish geologist by the name Sorby conducted an experiment.
He pressed a mixture of halite (salt) and biotite with a vice. The drawings on the right describe the result of the experiment.
Following his experiment, Sorby concluded that the unify (parallel) orientation of rocks like gneiss and schist were created as a result of high pressure and heat that influenced rocks that originally had a random orientation.



Hypothesis

6. Try to determine the directions of the pressure that created the orientation of crystals of the drawing above (circle the right drawing below).



Conclusion

7. A high pressure condition will cause to a rearrangement of the crystalline structure of a rock into a uniform orientation.

- The crystals elongate (circle the right option) ***in parallel / in perpendicular*** to the pressure direction.
- Such a change (circle the right option) ***needs / does not need*** a high heat conditions.
- Such a change can happened in (circle) ***liquid / only solid / both liquid and solid*** state.

What are the processes of metamorphism and what metamorphic rocks are?
As we concluded, high pressure may cause a change in the original structure of rocks and to change the arrangement of the rock's crystals from a random orientation to a uniform orientation. Such a change is called **metamorphism**, and such altered rocks (like schist and gneiss) are called **metamorphic rocks**. Metamorphism of high temperatures and pressures occur in the depth of the earth's crust (tens of kilometers). The metamorphic process occurs in the solid state, without the melting of the rock to magma.

Hypothesis

8. If metamorphic rocks are formed at a depth of tens of kilometers inside the crust and the mantle of the earth, how is it possible that we can find them on the surface?

____

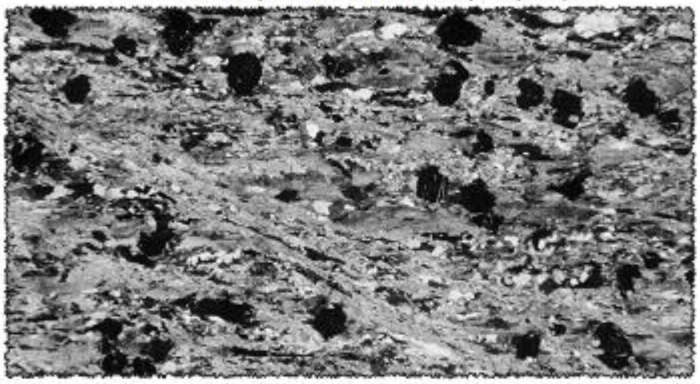
____

B. Changes to the mineralogy of the rock

In this section we'll see what we can learn about the metamorphic process through the exploration of the mineral **Garnet.**

What is Garnet?
Garnet is a mineral which is used as a gem. The Garnet crystal has a hexagonal shape (see illustration below) and might appear in different colors (from red to black).

A thin section of a rock sample with Garnet crystals (Magnification x 7)



Observation

1. Look at the rock on the tray, identify the crystals of the garnet mineral and complete the following sentences:

- The rock that contains the mineral garnet is ___________________

- The crystals of the minerals of this rock are arranged in a __________ orientation.

An American geologist named Tuttle built in the 1940s a sophisticated laboratory with an apparatus that can simultaneously create a very high temperatures and pressures. Tuttle introduced to this instrument various mixtures of minerals of igneous and sedimentary rocks and found that in a specific pressure and temperature, new minerals that were not

existed in the original mixture were created. These minerals are called **metamorphic minerals**.
It is important to note that the entire metamorphism process takes place in the solid state.
According to such lab experiments, it was found that the mineral Grant is created from a metamorphism of the mineral biotite in a temperature of 450 ^{0}C and in the pressure range of 2.5-4 Kb.

Observation

2. What are the observations indicating that the rock you explored was metamorphosed?

Observation A: ____

Observation B: ____

Conclusion

3. Following the experiments of Tuttle, what you can conclude about the types of rocks that can become metamorphic rocks (the source rocks for the metamorphic rocks)?

____

4. What can we conclude about the nature of the metamorphic process (circle the correct answer)?

a) The metamorphism is a mechanical process.
b) The process involves a slow crystallization rate of minerals from magma.
c) Metamorphism involves chemical disassembling and reassembling processes, in solid form.
d) The metamorphic process involves the crystallization of new minerals from a saturated solution.

Hypothesis

5. We concluded that the rocks are metamorphosed under high temperatures and pressures conditions.
What would happen to the metamorphic rocks if the temperature will increase (What type of a new rock may be formed by this process)? ______________________________

Conclusion

6. Lab analysis can tell us that some of the schist rocks that are exposed on the surface were primarily clay, which as we know, is a sedimentary rock.

- Describe **all** the processes of matter transformation that led to the transfer of clay to schist and then to the exposure of the schist to the surface. By doing it please use all the following concepts: *clay, sedimentary rock, surface, burial, the depth of the earth's crust, internal heat and pressure, metamorphism, metamorphic rock, schist, uplift, exposure, weathering, erosion, transportation, sedimentation*.

____

____

____

7. To summarize the metamorphic processes unit, complete the missing words in the blank spaces below:

In this activity, we examined two rocks: schist and gneiss. We saw that two rocks have a _______ structure, and in both of them the crystals are arranged in _________ _________ .

Following the experiment of Sorby we concluded that while a rock is in a high pressure condition its crystals elongated in________ to the direction of the pressure.

Therefore, we concluded that rocks like schist and gneiss formed under conditions of high _________, probably _________ in the earth's crust .

We also observed schist rocks that included the mineral garnet, which is a _________ mineral. Following the existence of the garnet we conclude that, in addition to a mechanical change, the process of metamorphism may also include a _____________ change.

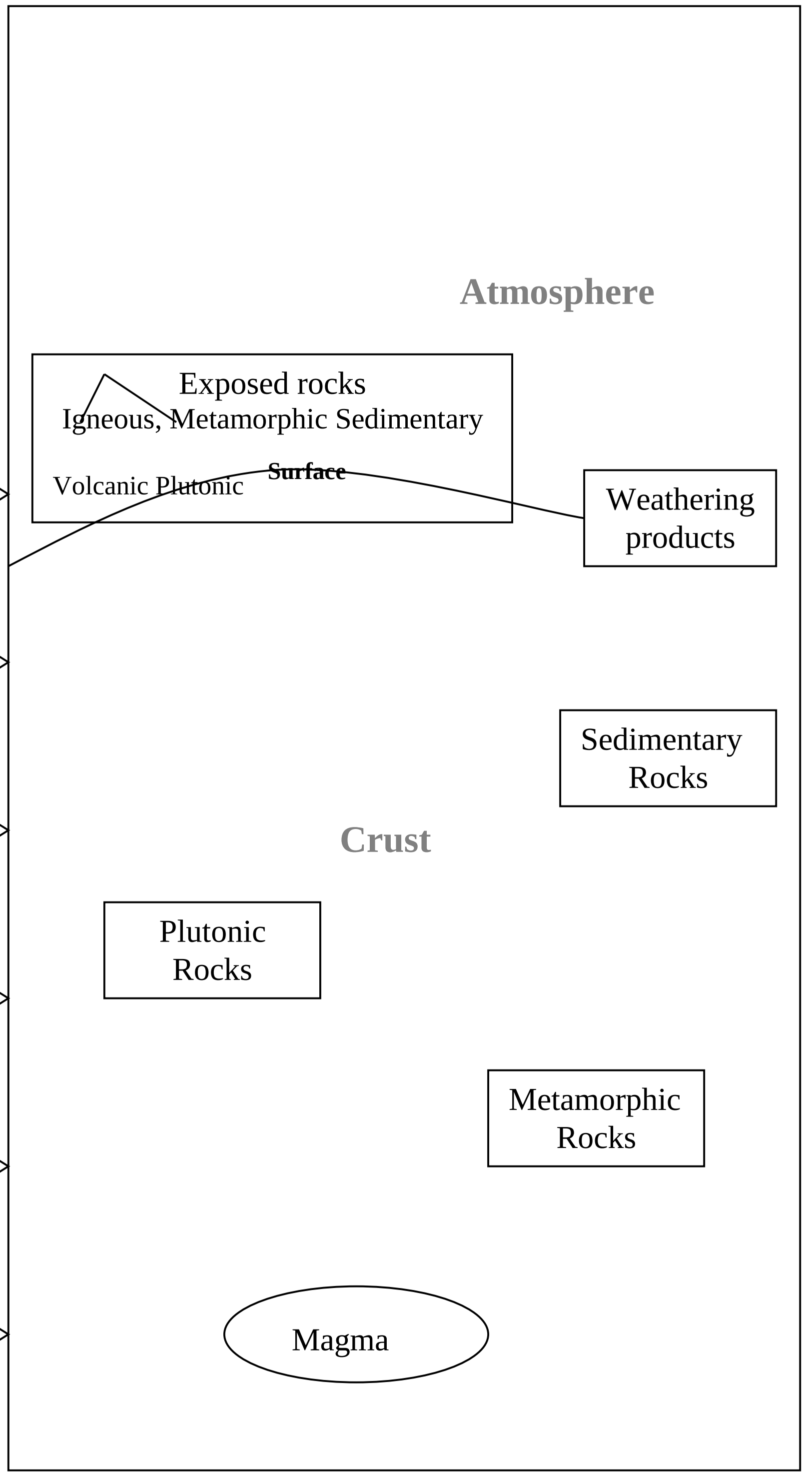
8. Complete the rocks' cycle activity in the next page.

A Rocks cycle summary

The following is a partial illustration of the rocks cycle. It includes only the components of the cycle (the rocks' reservoirs), but it doesn't include (yet) the processes that connect the different components of the cycle.
After each chapter you will visit this page and add the processes that you learned about in each chapter.

The procedure:

1. Circle the component of the rock cycle that you have just learned about.
2. Circle the processes that you have just learned about.
3. Connect any two components (rock reservoirs) that a matter can move between by an arrow and write on it the name of the process (from the list below) that can move the matter from one reservoir to another.



Processes:

Eruption and fast cooling

Uplift and exposure

Metamorphosis

Melting

Transportation, sedimentation, burial, lithification

Slow cooling

Weathering

Multiple Intelligences - Diagnostic activity:

Different students achieve understanding in different ways. There are those who understand better when they read written material. Some students find it easier to understand the way you use facts and figures that provide different arguments. There are those who understand best through activities that involve listening, rhythm, music, etc. Choose your preferred way of learning by following these instructions:

Choosing the style, you prefer: Place an X next to the statements that you agree with. The learning method that has the most Xs is likely the method that best suits you.

Learning Method 1

- I ask lots of questions about how things work. ☐
- I solve arithmetic problems quickly. ☐
- I like math. ☐
- I like to play chess, checkers, or other games of strategy. ☐
- I like to solve logic puzzles and other riddles. ☐
- I like putting things into categories or hierarchies. ☐

Total Score ___

Learning Method 2

- I write better than the average person. ☐
- I love creating stories and telling jokes and stories. ☐
- I enjoy verbal games. ☐
- I enjoy reading. ☐
- I like rhymes, puns, expressions formed by homonyms, etc. ☐
- I pay attention well by listening (listening to stories, programs, talk radio, audio books, etc.) ☐

Total Score ___

Learning Method 3

- I have the ability to identify songs, musical dissonance, or an instrument out of tune. ☐
- I remember the melodies of songs. ☐
- I play a musical instrument or sing in a choir or other choral group. ☐
- I hum a lot. ☐
- I am sensitive to environmental sounds (e.g., drops of rain falling on the roof). ☐
- I have a positive reaction when I hear music. ☐

Total Score ___

Learning Method 4

- I understand maps and graphics much more easily than text. ☐
- I like activities that have an artistic aspect. ☐
- I like drawing in complex ways. ☐
- I like puzzles, mazes, and other similar activities. ☐
- I like building relatively interesting 3D structures (e.g., using Legos). ☐
- I enjoy images more than text. ☐

Total Score ___

Learning Method 5

- I excel at one or more sports. ☐
- I move often, and have difficulty when I must sit in one place for a long time. ☐
- I like taking things apart and then putting them back together. ☐
- I like to play with everything I see. ☐
- I like running, jumping, wrestling, or similar activities. ☐
- I like working with clay /experimenting with other materials (e.g., painting landscapes). ☐

Total Score ___

This booklet was developed by Prof. Nir Orion and the Earth science group of the Science Teaching Department of the Weizmann Institute of Science.

Learning Method 1

Please demonstrate the rock cycle in your area by quantitative characteristics. For example, the distribution of type of rocks on earth; the rate of transportation of rock masses within the rock cycle; etc.

Learning Method 2

Please write a story: "My journey within the rock cycle – a story of a specific rock, mineral or soil that build my area".

Learning Method 3

Please write a RAP song: "The story of the rock cycle in my area".

Learning Method 4

Please demonstrate the rock cycle in your area by artistically: model, painting, etc.

Learning Method 5

Please demonstrate the rock cycle by a dance.

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