Earth Revealed VIDEO #18: Metamorphic Rock

This assignment can be found at: http://www.learner.org/resources/series78.html

PROGRAM 18 METAMORPHIC ROCKS

0:00-2:50 Remarks by series host

The human fascination with mountains is discussed. Reasons for their formation are presented. During the formation of mountains, tectonically active plates generate forces that deform the rocks. This change in the rock's form, due to heat and pressure, is called 01. ____________ . Metamorphism changes the appearance of rocks, their composition, and even their radiometric age. An explanation about how recrystallization occurs and its results is presented. Metamorphic rocks contain information about tectonic activity and Earth history.

2:51 -5:19 Interview with Douglas M. Morion, U.S. Geological Survey (with animation and images)

There is a wide variety of metamorphic rocks on Earth because there are so many different sedimentary, igneous, and other metamorphic rocks that can be changed by metamorphic processes. 02. ____________ , the original rock that existed before metamorphism, are shown with insets of the metamorphic rocks that form from them. There are a wide range of heat and pressure conditions deep inside mountains that can affect the creation of metamorphic rocks. The conditions required for the formation of metamorphic rocks are beneath the level of weathering and sedimentation that form 03. ____________ . A panorama of mountain ranges with folds is shown and its connection to metamorphic processes is explained. A geologist is shown taking a sample of metamorphic rocks from a folded outcrop. The specific conditions of heat and pressure and the depth inside Earth required to metamorphose rocks are explained. Animation is used to show how pressure applied at depth causes metamorphism. Also shown is a rectangle of rock, squeezed in different directions, showing the response to different 04. ____________ orientations? The structure of many metamorphic rocks is the result of 05. ____________ . Samples of schist, gneiss, and garnet-bearing schist are shown. Directed shear stress helps to explain the formation of snowball garnets.

A. Directed pressure	**B. Metamorphism**	**C. Protoliths**	**D. Sedimentary rocks**	**E. Stress**

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5:20-7:11 Interview with John Rosenfeld, University of California, Los Angeles (with demonstration)

Snowball garnets form in metamorphic rocks due to directed **06.** ________**.** Swirling images of snowball garnets are shown. Animation is used to show how snowball garnets form and what geologists learn about the metamorphic process from them. A multi-ringed model is used in the lab to show how metamorphism causes the snowball garnets.

7:12-9:23 Interviews with J. Lawford Anderson, University of Southern California; Douglas Morton

07. ________ involving compression helps to explain the formation of foliation, or layering in metamorphic rocks. Animation is used to show how minerals tend to grow perpendicular to the direction of directed stress and thus grow into layers, producing a **08.** ________ metamorphic rock. Images of the metamorphic rock schist are shown as examples of foliated rocks. Animation is also used to show that shear stress can cause layering in metamorphic rocks. Explanation is provided that shows how geologists use the layering in metamorphic rocks to learn about the stress field that was generated in a **09.** ________ environment. The intensity and direction of the **10.** ________ can be determined. The way that foliation affects the strength of rocks and why this is important to engineers is presented. Constructing roads, dams, or foundations on foliated rocks can cause severe problems. Information is provided that shows and explains what engineers must do when working with metamorphic rocks.

A. Directed stress	**B. Foliated**	**C. Shear stress**	**D. Stress field**	**E. Subduction zone**

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9:24-12:12 interview with John Rosenfeld (with animation and images)

In addition to directed stress, rising temperatures will cause minerals to react and form new crystal lattices and mineral types. This process, called 11.__________ **,** generally causes minerals to grow larger. For example the fine grains in sedimentary limestone recrystallize into large interlocking crystals of calcite in the formation of marble. Images of various recrystallized metamorphic rocks are shown. Animation is also used to show the crystal lattice within minerals. Animation is used to show partial melting of one tectonic plate subducting under another Sometimes the heat is so great that the rocks undergoing change start to melt. When this happens, a rock called 12.__________ **,** displaying features of both igneous and metamorphic rocks, will form. Evidence is shown that migmatites provide clues for one of Earth most common igneous rocks, 13.__________ **.** It is now understood that rocks undergo changes in composition during the metamorphic process. The change shows up as liberation of water causing the rocks to dry out. Heat is the cause of this loss of water and other 14.__________ such as carbon dioxide. The affect that migrating fluids might have on rocks is explained. In general, the diversity of metamorphic rocks is created by the numerous 15.__________ **,** the presence of fluids and the wide range of temperatures and pressures possible within Earth.

A. Granite	**B Migmatite**	**C. Protoliths**	**D. Recrystallization**	**E. Volatiles**

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12:13-15:12 Remarks by series host • Interview with Douglas Morton (with images)

Under various amounts of heat and pressure, changes that occur in metamorphic rocks involve both texture and mineral content. The specific changes that occur depend on a variety of factors including the composition of the protolith, the amount of heat and pressure applied the amount of time of metamorphism, and whether or not water is present. The processes involved in 16. ________ metamorphism and 17. ________ metamorphism are described. Major differences in the two basic ways that metamorphic rocks form are explained and shown with images. Heat is the major factor involved with contact metamorphism whereas 18. ________ are involved with regional metamorphism. Chemical changes that accompany changes due to contact metamorphism ate described and shown with images. An example of the igneous rock tonality in contact with limestone is shown and the mechanism of silica migration is explained. An outcrop of layered metamorphic rock that formed by regional metamorphism is shown. The layering in this outcrop was caused by tectonic forces in which a great deal of directed shear stress was applied.

15:13-18:05 Remarks by series host

A chart of 19. ________ is used to explain the combined variables of protolith, temperature, and pressure (depth) in the formation of metamorphic rocks. Because specific metamorphic rocks form under certain conditions of heat and pressure, the chart can be used by geologists to determine the conditions under which a specific metamorphic rock has formed. 20. ________ changes that occur in specific rocks with changing conditions of temperature and pressure are described. The example of basalts containing amphibole and zeolites are presented. The position relating to temperature and pressure and thus metamorphic grade of these rocks is shown on the chart. Metamorphic changes occur by increasing grade from low to high and this chart can be used to plot and study the predictable nature of metamorphic alteration.

A. Contact metamorphism	**C. Heat and pressure**	**E. Metamorphic fades**
B. Mineralogical	**D. Regional metamorphism**	

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18:06-20:25 Interview with Douglas Morton (with animation and images)
The stages of progressive metamorphism are explained and shown with images of several metamorphic rocks. 21.________, for example, as a protolith would change first to layered slate, then with more metamorphism, the slate changes into 22.________. With more heat and pressure, 23.________ forms. Schist's form at rather high metamorphic grade. At higher metamorphic grade, minerals segregate into definite layers and a 24.________ forms. Images are used with superimposed graphics of chemical reactions to explain why metamorphic changes do not reverse as conditions return to lower temperatures and pressures. This is also partly explained by animation showing that ion migration is much more difficult in rocks at lower temperatures and pressures. In most metamorphic rocks, geologists find a permanent record of the greatest temperatures and pressures that occurred during crustal 25________.

A. Claystone	**B. Deformation**	**C. Gneiss**	**D. Phyllite**	**E. Schist**

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20:26-25:05 Remarks by series host • Interview with John Rosenfeld (with images and animation)

Animation is used to demonstrate the relationship that metamorphic processes have with plate tectonics. With the development of the plate tectonics theory, the high temperatures and pressures involved with forming metamorphic rocks began to make sense. Plate tectonics has enabled geologists to explain the relationship between metamorphic faces and the metamorphic **26** . The example of blueschist formation is used to explain this relationship. The very special conditions needed to form blueschist would exist in a tectonic **27**. . Metamorphic rocks provide geologists with the most complete picture of temperatures and pressures that rocks undergo during plate collision.

28. of the formation of snowball garnets in Vermont can be used to describe how fast the snowball garnets formed. Animation is used to show the formation of the supercontinent **29**. . By studying the formation of snowball garnets in the rocks of Vermont, geologists can determine the deformation rate occurring during the formation of Pangaea.

25:06-end Remarks by series host

The abundance of metamorphic rocks and how they are used to study Earth's history are discussed. The link between metamorphic processes and tectonic activity, especially mountain building and plate motion, is reviewed. **30** is a consequence of plate tectonics. Finally, an overview of the process of metamorphic rock formation as it relates to the rock cycle is presented.

A. Environment	**C. Metamorphism**	**E. Pangaea**
B. Radiometric dating	**D. Subduction zone**	