

■ Igneous Rock

Rock types

Igneous rock is one of the three main rock types, the others being **sedimentary** and **metamorphic**. When **magma** cools and hardens, it **forms** igneous rock. The term igneous comes from an old Latin word, *ignis*, which means "fire" because early geologists often associated igneous rocks with hot **molten** material called **lava flow**. Lava is magma that flows out onto Earth's surface. Igneous rocks are **classified** based on their **texture**, and their chemical and **mineralogical compositions**.

Textures of Igneous Rocks

The texture of igneous rocks depends on how quickly magma or lava cooled when it was formed. Magma that cools deep inside **the crust** forms **intrusive igneous rock**. The magma then slowly cools and hardens. Lava that cools at the Earth's surface forms **extrusive igneous rock**. This magma cools much faster than intrusive igneous rocks.

• Coarse-Grained Igneous Rock

Intrusive igneous rocks commonly have large mineral **grains**. The slow cooling enables minerals to grow large. The texture of igneous rock that is composed of large mineral crystals is a **coarse-grained texture**.

• Fine-Grained Igneous Rock and Porphyritic texture

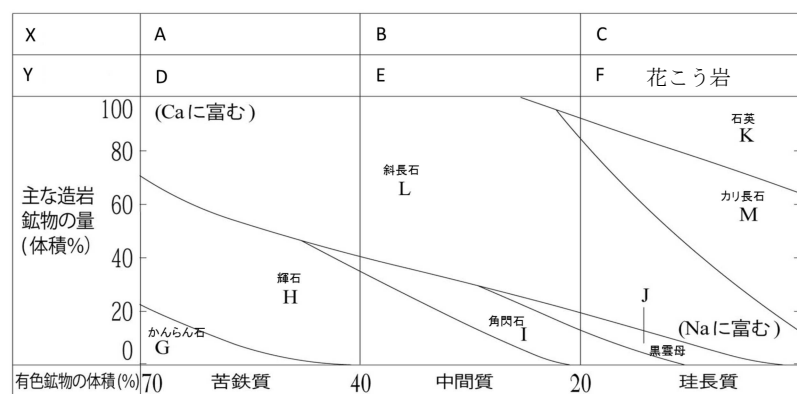
Many extrusive igneous rocks have small mineral grains that cannot be seen with the naked eye. Because minerals crystallize too rapidly to form large crystals. The texture of igneous rocks composed of small crystals is a **fine-grained texture**.

When the conditions during cooling of magma changes relatively quickly, **porphyritic textures** develop. When magma slowly crystallizes below a volcano but the volcano **erupts** before completing crystallization, the remaining lava crystallizes more rapidly to form much smaller crystals. The texture of igneous rocks that **include** some larger crystals in its matrix of small crystals has a porphyritic texture.

Understanding Main Concepts

1. Fill in the brackets.

extrusive igneous rock,
basalt, andesite, rhyolite,
intrusive igneous rock,
gabbro, diorite, granite,
olivine, pyroxene,
hornblende, biotite,
quartz, plagioclase,
potassium feldspar,



2. Which magma type contains the greatest amount of SiO₂?

- a. basaltic b. rhyolitic c. andesite

■ Volcanoes

Lava

What situation do you imagine when you hear a volcano has erupted? Do you picture clouds of **ash** being thrown violently into the air? Or do you imagine rivers of reddish-orange lava flowing down the slopes of a steep volcanic peak? Both of these represent that Earth is indeed geologically active.

Types of Volcanoes

The **viscosity**, or **resistance** to the flow of magma affects the shape of the volcano and the "violence" or **explosiveness** of a volcanic eruption. The viscosity of magma is **determined by** the magma's composition. **Rhyolitic magma** that contains large amounts of **dissolved** gases is more likely to produce explosive eruptions than **basaltic magma** that contains small amounts of dissolved gases. One of the most dangerous kinds of eruptions, especially an eruption from a **silica** rich volcanos, is **pyroclastic flow**. Pyroclastic flow is a mixture of hot gas (about 1000°C), **pumice** and **volcanic ash** that moves down volcanic slopes at a very high speed.

Based on the type of material that forms the volcano and the type of eruptions that occur, three major types of volcanoes have been identified: **shield volcanoes**, **Stratovolcanoes**, and **lava domes**.

- **Shield volcanoes**

Volcanic cones that are broad at the base and have gently sloping sides.

- **Stratovolcanoes**

Tall, conical volcanoes composed of one **layer** of hardened lava, **tephra**, and volcanic ash.

- **Lava domes**

Steep-sided, round-shaped mounds formed from **viscous** lava that solidifies immediately above a **volcanic vent**.

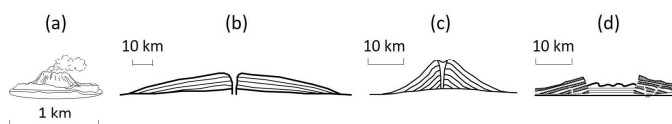
Volcanic Products

The main products of volcanoes are lava, ash, pumice and gases.

Understanding Main Concepts

1. What kind of volcano is shown in the diagram?

- a. lava dome b. shield volcano
- c. stratovolcano d. caldera

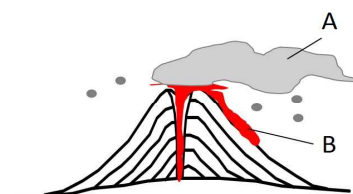


2. What kind of volcanic feature is designated by the letter A?

- a. lava b. volcanic gases c. tephra (volcanic ash, pumice)

3. What kind of volcanic feature is designated by the letter B?

- a. lava b. volcanic gases c. tephra



4. Which of the following has broad, gently sloping sides and a circular base?

- a. shield volcano b. Stratovolcano c. lava dome

【Vocabulary】

本文 (Igneous Rock)			
igneous rock	noun	火成岩	rock that is formed by solidification of cooled magma
sedimentary rock	noun	堆積岩	rock that is formed by deposition of sediment
metamorphic rock	noun	変成岩	rock that is formed by the action of heat or pressure
magma	noun	マグマ	very hot liquid rock found below the earth's surface
form	verb	形成する	
molten	noun	溶けた	
lava	noun	溶岩	hot liquid rock that comes out of a volcano
flow	noun	流れ	lava flow: 溶岩流
classify	verb	分類する	
texture	noun	組織	
mineral	noun	鉱物	
composition	noun	組成	the different parts which something is made of
the crust	noun	地殻	the part of the earth above the mantle
intrusive igneous rock	noun	深成岩	
extrusive igneous rock	noun	火山岩	
grain	noun	粒	a small hard piece of particular substances
coarse-grained texture	noun	粗粒組織	
fine-grained texture	noun	細粒組織	
porphyritic texture	noun	斑状組織	
erupt	verb	噴火する	
include	verb	～を含む、包含する	to make something part of something
本文 (Volcanoes)			
ash	noun	灰	powder that is left after something has burned
viscosity		粘性	the quantity that describes a fluid's resistance to flow
resistance	noun	抵抗	
explosiveness	noun	爆発性	
be determined by		決定される	
rhyolitic magma	noun	流紋岩質マグマ	
dissolve	verb	溶ける	
basaltic magma	noun	玄武岩質マグマ	
silica	noun	ケイ素	
pyroclastic flow	noun	火砕流	a hot avalanche of hot lava fragments and gas
pumice	noun	軽石	stone that comes from volcanoes and is very light in weight
volcanic ash	noun	火山灰	very fine rock and mineral particles less than 2 mm in diameter that are ejected from a volcanic vent
shield volcanoes	noun	盾状火山	volcanic cones that are broad at the base and have gently sloping sides
stratovolcanoes	noun	成層火山	a conical volcano built up by many layers of lava, pumice and volcanic ash
lava dome	noun	溶岩円頂丘	rounded, steep-sided mounds built by magma that is highly resistant to flow
layer	noun	層、重ね	
tephra	noun	テフラ、火山砕屑(さいせつ)物	rock fragments and particles ejected by a volcanic eruption
volcanic vent	noun	火口	

■ Volcanic Disasters -Probe the Secret of "Sapporo-Nanseki"-

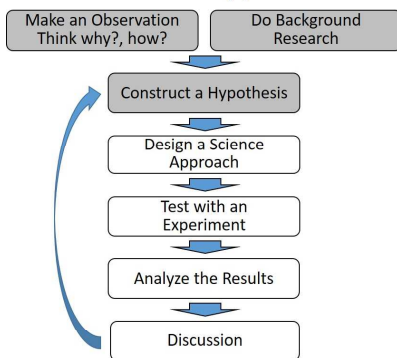
English Science

Words learned through English Science



Construct a Hypothesis –the use of logical thinking–

Scientific Approach



● 科学研究は、自然事象・現象を観察したときに生じる「なぜ？」という疑問から始まります。その「なぜ？」の答えを導き出す方法として、「仮説」を設定する過程を学びました。仮説は、実験、観察、調査等により真偽判定できる命題です。

ここでは、観察されたいくつもの事実の集合から出発して、それらの事実をうまく説明できる最良の説明を論理的に推論する過程に着目して、「仮説形成」を行っていきましょう。

It's Your Turn -Activities with TA-



confirm : 確かめる

【Role play】

A: How do we confirm whether this rock is a sedimentary rock or an igneous rock?

B: We can confirm it by checking whether this rock is attracted to the magnet.

sedimentary rocks ? igneous rock



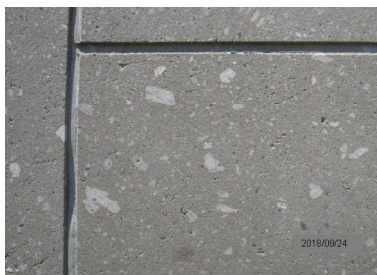
by checking



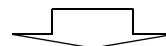
attract

1 Initial Observation

Observe the sample of "Sapporo-Nanseki". Explain the characteristics of "Sapporo-Nanseki" from the result of the fire resistance experiment so that you can fill the space below.



- The weight is (heavy / light).
- From the fire resistance experiment, it is understood that (it has heat-insulating properties / it is easy to catch fire).
- It is easy to obtain from the outcrop (露頭).



Sapporo-Nanseki was used as () material from the Meiji era to the Beginning of the Showa era.

Initial Question : How was Sapporo-Nanseki formed?

2 Background Research & Information Gathering

Now you want to find out how Sapporo-Nanseki was formed. In groups, investigate the occurrence and the characteristic of the rock and collect related information. The TA's will help you so that you can fill the space below.

Investigation 1 (Distribution & Occurrence)

Search the other places where you can find the same rock.

【TAs Question】

Q1.

【Your Answer】

→ reply

quarry:採石場



出典：地理院地図（電子国土 Web）

→ reply; Sapporo Dome is ...

Q2.

Occurrence of Sapporo-Nanseki (④)



Sapporo-Nanseki

Q3.

→ reply

I think Sapporo-Nanseki is...

Q4.

→ reply

I think it is about.....

Q5.

→ reply

I think we will find.....

Describing Events -Investigation 1-

- We can find/see Sapporo-Nanseki widely from _____ to _____.
- Sapporo Nanseki is sandwiched between a large amount of _____.
- The height of volcanic ash is _____ m.

Investigation 2 (The analysis of Sapporo-Nanseki and a rock containing a record of its history)

Observe Sapporo-Nanseki closely.

【TAs Question】

By showing the sample of a container,

Q1.

Q2.

By showing Sapporo-Nanseki,

Q3.

Q4.

Q5.

【Your Answer】

→ reply

→ reply

→ reply

→ reply

→ reply



by checking



attract



■ Describing Events -Investigation 2-

- Sapporo-Nanseki is an _____ rock and contains _____ which are the same as ones included in the volcanic ash on both sides.

Investigation 3 (Background Knowledge)

Watch the video spoken in Japanese and tell TA about the contents of it by replying TA's questions.

*ビデオの情報（どこ、いつ、何m、何回）を素早くメモしよう。

【TAs Question】

After students watch the video,

Q1.

Q2.

Q3.

Q4.

Q5.

Q6.

Q7.

【Your Answer】

→ reply

→ reply

→ reply

→ reply

→ reply

→ reply

→ reply



■ Describing Events -Investigation 3-

- Shirasu is a **volcanic ash deposit** caused by the Aira _____ eruption.
- This _____ m height deposit formed by the _____ by the only eruption that occurred here _____ thousand years ago.

Investigation 4 (Interpret the rock layers, draw information recorded within its layers)

Let's move on to the exhibit ! Read information from the stratum.

stratum : 地層

【TAs Question】

By looking the exhibit from a distance,
Q1.

Q2.

By looking at the exhibit at close range,

Q3.

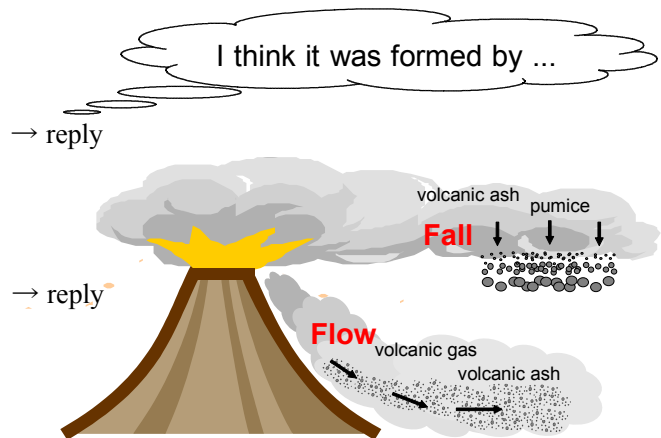
Q4.

【Your Answer】

→ reply



→ reply



→ reply

→ reply

Describing Events -Investigation 4-

Logical Thinking



Character

Layer structure is

(clear / not clear) → (Flow / Fall)

↓

(pyroclastic flow / ash fall)

Layer structure is

(clear / not clear) → (Flow / Fall)

↓

(pyroclastic flow / ash fall)



- The volcanic ash on both sides of Sapporo-Nanseki has no layer structure so that the ash is a _____ deposit.

Investigation 5 (Interpret the rock layers, draw information recorded within its layers.)

Let's move on to the exhibit ! Read information from the stratum.

stratum : 地層

【TAs Question】

By looking at the exhibit at close range,
Q1.

By showing pictures,
Q2.

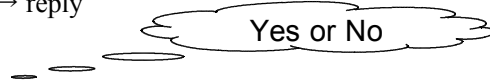
Q3.

Q4.

Q5.

【Your Answer】

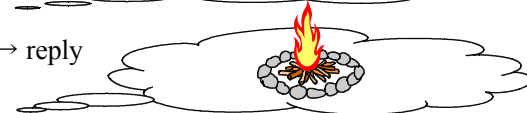
→ reply



→ reply



→ reply



→ **Think Logically** and fill in a bracket.

Natural wood was burned in the heat of _____
_____ with little air.

carbonized wood: 炭化木

► Describing Events -Investigation 5-

- Volcanic ash was still _____ when it came to this place because there is carbonized wood in it.

Additional Information 1

The relation between the volcanic ash erupted by Shikotsu Caldera and that of Sapporo-Nanseki.



Volcanic ash and pumice
around Chitose

the same



Sapporo-Nanseki

► Describing Events -Additional Information 1-

- We know that there is Lake Shikotsu near Chitose. Shikotsu caldera was formed by the large volcanic eruptions 40 thousand years ago.
- Moreover, the volcanic ash of Sapporo- Nanseki **is the same as** that of Shikotsu caldera.

Additional Information 2

Watch the video and answer the TA's questions about the video.

【TAs Question】

Q1. What is the name of this huge round shaped depression/low land?

⇒ This is called Aso Caldera.

Q2. When did Aso caldera have a large eruption?

⇒ It was 90 thousand years ago.

Q3. In the simulation, what do you call the hot avalanche/mixture of volcanic ash and volcanic gas? It spread in many different directions.

⇒ It is called pyroclastic flow.

Q4. What is the temperature and the speed of the pyroclastic flow?

⇒ Its temperature is more than 800 °C and it's speed is 900km/h.

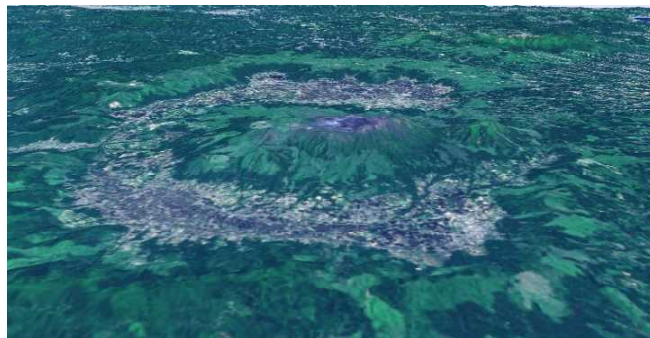
Q5. How many minutes will it take for pyroclastic flow to move from Aso to Fukuoka if Aso Caldera erupts again?

⇒ About 8 minutes.

Q6. What is the name of the huge volcanic eruption in the video?

⇒ The name is Caldera eruption.

【Your Answer】



出典：地理院地図（電子国土 Web）

NHK スペシャル「巨大災害」
9万年前の「カルデラ噴火」がもしも
今起きたら（視聴）

3 Construct a Hypothesis

● **Aim of your research** : To clarify how Sapporo-Nanseki was formed.

Now you discovered many facts from Investigation 1 to Investigation 5 and gathered information . How would you interpret these discoveries? Your initial question is "How was Sapporo-Nanseki formed?". Your initial question includes two things; "What is **the process** of how Sapporo-Nanseki was formed?", and "What is **the origin** of Sapporo-Nanseki?".

Activity 1

Now you want to find out the process and the origin of Sapporo-Nanseki. Which facts relate more closely to which question; question about the process or question about the origin? Discuss in groups and divide the facts into two categories.

Question about the process	Question about the origin

Activity 2

Think logically, step-by-step manner and make appropriate explanations to connect observed facts. Then construct hypothesis about two categories above. **Fill in the spaces to complete the sentences.**

•Question about the process

Investigation 2

→ Igneous rock.
→ Same pumices as ones included on both sides.

Investigation 5

→ Volcanic ash was still very hot.

Investigation 1

→ The height of volcanic ash is 40m (very thick).

Investigation 2

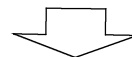
→ Many flattened pumice fragments can be seen in the ash.

Hypothesis

Sapporo-Nanseki was formed from volcanic ash receiving _____ and the _____ of its own ash.

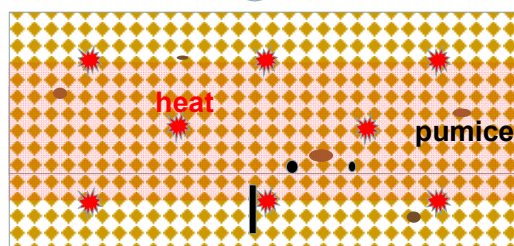
Logical Thinking

- Sapporo-Nanseki must be made from _____ on both sides.
- If so, how does volcanic ash become _____?



- The ash must be very heavy because ash is very thick, so that the shape of pumice became _____ through the compression of ash.
- The ash must accumulate _____ because the ash was still hot, so that ash sticks together to become a hard rock through the heat.
- That reminds me, ash consists of many volcanic glasses.

Compression



•Question about the origin

Investigation 1

→ From Sapporo to Eniwa.

Investigation 4

Layer structure is not clear.
→ Pyroclastic flow.

Investigation 3

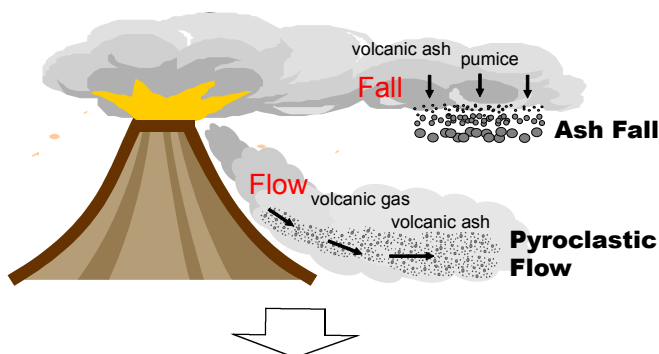
→ Caldera eruption.

Additional information 1

→ 40 thousand years ago.
→ Same ash as one of Shikotsu caldera.

Logical Thinking

- Mixture of volcanic ash and pumice must came from _____ as a _____ and covered the area from Chitose to Sapporo because Shikotsu caldera was formed by the huge eruption 40 thousand years ago.



Hypothesis

Sapporo-Nanseki was formed by the accumulation of _____ which originated from Shikotsu caldera eruption.

Extensions -How will you test the two hypothesis above?-

• Question about the process

In order to test the hypothesis, we examined conditions of hardness on temperature using ash from the nonwelded base. The experiments was conducted at 1 MPa in a muffle furnace. The welding process of ash was observed.



▶ Drawing Conclusions

Our experimental results **demonstrate** the process that the ash is compacted into a solid rock by the heat and compression.

• Question about the origin

If Sapporo-Nanseki originated from Shikotsu caldera eruption, the same rock layer as Sapporo-Nanseki must be found around another caldera lake. In order to test the hypothesis, we investigated whether the same rock layer as Sapporo-Nanseki is found around Lake Kuttara. We found the same rock layers in the pyroclastic flow deposits around Lake Kuttara.



▶ Drawing Conclusions

Our findings appear to give strength to the hypothesis that Sapporo-Nanseki was formed by the pyroclastic flow came from Shikotsu caldera.

▶ Applying Conclusions

About 40,000 years ago the volcano erupted producing a large amount of ashfall and pyroclastic flow. The large pyroclastic flow at this time surged over the southern part of Sapporo. When the pyroclastic flow came to this place, it was still very hot, so that Sapporo-Nanseki was formed by the heat and the compression of the volcanic ash.

● Hazard map

【TAs Question】

Q1. This is called a hazard map. How do you say

Hazard map in Japanese? ⇒ Bousai map.

Q2. What does this arrow shows?

⇒ It shows the direction of wind of upper air.

Q3. What does this area shows?

⇒ It shows the area covered by volcanic ash if Mt. Use erupts.

Q4. What does this area show?

⇒ It shows the area covered by pyroclastic flow if Mt. Use erupts.

【Your Answer】



北海道伊達市 : <https://www.city.date.hokkaido.jp/hotnews/detail/00000764.html> (accessed 2015-06-20)

The Sapporo Streetcar

Around the beginning of Meiji-era, Sapporo-Nanseki cut out at the Ishiyama quarry were carried to the center of Sapporo by suspending them on a horse's back. Later together with the increase of demand,



"Sapporo Stone Horsecar Railway" was opened in 1909 in order to carry Sapporo-Nanseki to the center of Sapporo. Then it was electrified in 1918 as the Sapporo Streetcar. This is the history of the Sapporo Streetcar.

Scientific Communication



日本語では根拠を挙げる言葉に「示す」がありますが、英語には根拠を挙げる言葉がいろいろあります。また、日本語に比べて、英語では、同じ言葉の繰り返しが嫌う傾向が強いといわれています。根拠を挙げる言葉をどう使い分けると良いのかを、今回の授業を通して考えてみましょう。

ジーニアス英和辞典より

- prove : 〈人・物〉が、…であることをはっきり示す《prove は show と違って疑いの余地を残さないことをいう》。
- demonstrate : 〈学説・真理など〉を […ということ] (推論・証拠などによって) 論証する、証明する《prove の方が適用範囲が広い》。
- reveal : 〈人が〉〈(通例知られていない) 事〉を […であることを] 明らかにする、示す。〈(通例隠されている) 物を〉をみせる。
- show : 〈人・物が〉〈物・事〉を見せる、示す。
- indicate : 〈人・物が〉(手・指などで) …を […であることを] 指し示す。

Exercise 1

You are going to explain the origin of Sapporo Nanseki by using the slide and script below. Choose the most suitable sentence to fill the blank from the following ①～④.



- Sapporo Nanseki is sandwiched between a large amount of volcanic ash like shown in this picture.
- By the way, where do you think the volcanic ash came from?
- _____
- This reveals that Sapporo-Nanseki was formed by the large eruptions of Shikotsu caldera.

- ① Sapporo-Nanseki has pumice from both sides of volcanic ash.
- ② Shikotsu caldera was formed by the large caldera eruption 40 thousand years ago.
- ③ The volcanic ash of Sapporo-Nanseki is a pyroclastic flow deposit.
- ④ The volcanic ash of Sapporo-Nanseki is the same as Shikotsu caldera that erupted 40 thousand years ago.


[Presentation Exercise]

Let's try to have a presentation using the following slides and script.

Introduction

Volcanic Eruptions
and the Benefits of Volcanoes

"Sapporo-Nanseki"



How was
Sapporo-Nanseki
formed?

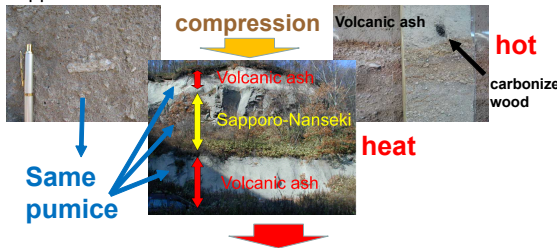
- It is easy to obtain from the outcrop.
- There is a heat-insulating property.
- It is used as building material.

Body 1

Cause of the formation

Pumice included in the Sapporo-Nanseki

Carbonized wood included in the volcanic ash.



compression

Volcanic ash

hot

carbonized wood

heat


Same pumice

Sapporo-Nanseki was formed by the heat and the compression of the volcanic ash.

Body 2

Where did the volcanic ash come from?

- **Shikotsu caldera**
 - 40 thousand years ago
 - By large volcanic eruptions



Sapporo-Nanseki

Shikotsu caldera

Same Volcanic ash


Conclusion

Conclusion

Volcanic activity

disasters

benefits



Coexist with the volcano

- My name is _____.
- I will be talking about volcanic eruptions and the benefits of volcanoes.
- This is Sapporo-Nanseki which is used as building material.
- Do you know how Sapporo-Nanseki was formed?
- OK, I'll explain it to you.

- Sapporo Nanseki is sandwiched between a large amount of volcanic ash like shown in this picture.
- Carbonized wood included in the volcanic ash shows that the ash was still very hot when it came to this place.
- Sapporo-Nanseki has pumice from both sides of volcanic ash. In addition, the pumice is flattened.
- These facts **indicate** that Sapporo-Nanseki was formed by the heat and the compression of the volcanic ash.

- By the way, where do you think the volcanic ash came from?
- The volcanic ash of Sapporo-Nanseki is the same as Shikotsu caldera that erupted 40 thousand years ago.
- This **reveals** that Sapporo-Nanseki was formed by the large eruptions of Shikotsu caldera.

- In conclusion, volcanic activity brings us not only disasters but also benefits.
- We can say that we have coexisted with the volcano for many years.
- Thank you for listening.