Let's Read !

■ Geological History of Earth

Sedimentary Rock

Sedimentary rocks are formed from the breakdown of **existing rocks** through the **action** of water. The **layers** of **sediment** were once **deposited** in the bottom of seas and over millions of years they **compacted** to form rock. Imagine the falling snow **piling up** high. Which snow is older, the bottom or top? Scientists use a basic **principle** called **the law of superposition** to determine the **relative age** of a layer of sedimentary rock. The law of superposition is that the youngest rock is always on top and the oldest rock is always on the bottom if you're looking at an **outcrop** that has layers of different **strata**, and that outcrop is unreformed.

Index fossils

Fossils are the remains of ancient plants and animals or evidence of their presence. By using the law of superposition, geologists can use fossils to **determine** the relative ages of the rock layers in which the fossils are located. Fossils found only in rock layers of a particular geologic age are called **index fossils**. To be an index fossil, a fossil must have certain **features**. It must be widespread, easy-to-identify at species level and have had a short **life span**.

Facies fossils

Some fossils can be found only in certain environments, and they allow us to learn about the environmental **conditions** of that **period** when the covering layer was deposited. These fossils are called **facies fossils**.

Ammonites appeared during the **Devonian period** and became **extinct** at the end of the **Cretaceous period**, 65 million years ago. Ammonites are important index fossils and facies fossils because of their wide geographic **distribution** in **shallow** marine waters, rapid **evolution**, and features that can easily be recognized. For example, Ammonites are found in large numbers in Nepal at the **elevation** of around 3,600 m **above sea level**. This is one of the proofs that the Himalayas were once under water during the **Mesozoic era**.

The geologic time scale

The **geologic time scale** is used by geologists and other scientists to map the timing and relationships between **events** that have occurred during the history of the Earth from its origin 4.6 billion years ago to the present. The geologic time scale is shown in Figure 1.

Era 代	Period 紀	Epoch 世	Beginning of interval in Ma	Hokkaido
Cenozoic 新生代	Quaternary 第四紀	Holocene 完新世	0.01	
		Pleistocene 更新世	2.6	
	Tertiary Neogene 新第三紀	Pliocene 鮮新世	5.3	
		Miocene 中新世	23	
	Tertiary Paleogene 古第三紀	Oligocene 漸新世	34	
		Eocene 始新世	56	Ishikari Group 石狩層群
		Paleocene 暁新世	66	
Mesozoic 中生代	Cretaceous 白亜紀		145	Hakobuchi Group 函淵層群 Ezo Group 蝦夷層群
	Jurassic ジュラ紀		201	Sorachi Group 空知層群
	Triassic 三畳紀		252	
Paleozoic 古生代	Permian 二畳紀		299	
	Carboniferous 石炭紀		359	
	Devonian デボン紀		419	
	Silurian シルル紀		443	
	Ordovician オルドビス紀		485	
	Cambrian カンブリア紀		541	
Precambrian time 先カンブリア時代			4,600	

Figure 1. Geologic time scale

Understanding Main Concepts

1. What are solid particles that have been deposited on Earth's surface called?
   a. outcrop **b.** fossils **c.** lava **d.** sediments

■ Plate Tectonics

Continental Drift

It is difficult for us to understand that Earth's surface is moving because the scenery does not change during the lifespan of a human being, with a few exceptions, such as **landslides** after heavy rain or **faults** after earthquakes. In 1912, Alfred Wegener proposed the idea of "**continental drift**" to the scientific community.

Continental drift is the theory that there was a **supercontinent** which joined as a single continent, Alfred Wegener called this **Pangaea**, but it began to break about 200 million years ago and moved slowly to form the present positions of continents.

Plate Tectonics

By the 1960s, evidence which supports the theory of continental drift such as the **distribution** of **terrestrial heat flow** and **seafloor spreading** were gathered.

Plate tectonics is the theory that the Earth's surface is divided into 20 main hard **massive** sections called **tectonic plates** which move in different directions, and this explains the cause of geologic events such as earthquakes, volcanic eruptions and mountain formation.

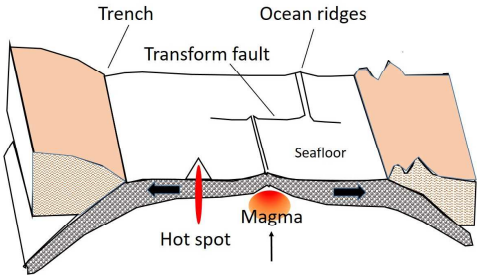


Figure 2. Plate boundary

Tectonic plates **interact** at places called **plate boundaries**. There are three types of plate boundaries, as shown in Figure 2. The type of plate boundary determines what sort of geologic events occur.

- **Divergent Boundaries**

  The places where two tectonic plates are moving **apart** are called **divergent boundaries**. Most divergent boundaries are located on the **seafloor**, where they form **ocean ridges**. A large amount of magma **erupts** at the ocean ridges, the magma cools rapidly to form **pillow lava** which is the **uppermost** layer of the **lithosphere**. This process is called Seafloor spreading.

- **Convergent Boundaries**

  Places where two tectonic plates are moving towards each other are called **convergent boundaries**.

  There are two types of convergent boundaries. When an **oceanic plate sinks** under the less **dense continental plate**, it forms a very deep **depression** in the ocean floor called a **trench**. When two plates made of continental lithosphere collide, large **mountain ranges**, such as the Himalaya Mountains, are formed.

- **Transform Boundaries**

  The place where two plates slide horizontally past each other forms a **transform fault** between those two plates.

Hot Spots

Hot spots are places where pipe shaped **mantle plumes** that are not directly related with plate tectonic processes are rising. There are few hot spots on Earth, an example is the one under Hawaii. While the hot spot itself is fixed, the **pacific plate** is still moving. As a result, a **trail** of **seamount** forms in **the Pacific Ocean**.

Understanding Main Concepts

1. What plate boundary is japan located on?
   a. divergent boundary **b.** convergent boundary **c.** transform boundary

2. New ocean floor is constantly being produced through the process known as
   a. subduction. **b.** continental drift. **c.** sea-floor spreading. **d.** island arc-trench system.

【Vocabulary 1】

本文 (Geological History of Earth)			
sedimentary rock	noun	堆積岩	rock that is formed by deposition of sediment
existing rock		既存の岩石	
action	noun	働き	a thing done
layer		層	a sheet or thickness of material
sediment	noun	堆積物	particulate matter carried by water or wind and deposited on the land surface or seabed
deposit	verb	沈殿する、堆積する	to leave a layer of something on the surface of something, especially gradually and over a period of time
compact	verb	圧縮する、固める	exert force on to make more dense
pile up		積もる	
principle	noun	原理、法則	a general or scientific law that explains how something works or why something happens
the law of superposition	noun	地層累重の法則	
relative age	noun	相対年代	
outcrop	noun	露頭	a rock formation that is visible on the surface
strata	noun	stratum の複数形 stratum: 地層	a layer of a series of layers of rock
fossil	noun	化石	the remains of an animal or a plant which have become hard and turned into rock
determine	verb	決定する	to discover the facts about something
index fossil	noun	示準化石	a fossil used to define and identify geologic periods
feature	noun	特徴	
life span	noun	生存期間	
condition	noun	状態、条件	
period	noun	時代	a length or portion of time
facies fossil	noun	示相化石	a fossil that allows us to define the ancient depositional environment
Ammonite	noun	アンモナイト	
Devonian period	noun	デボン紀	
extinct	adj	絶滅した	having no living members
Cretaceous (period)	noun	白亜紀	
distribution	noun	分布	
shallow	adj	〈水、くぼみ〉浅い	of little depth
evolution	noun	進化	the gradual development of plants, animals, etc. over many years as they adapt to changes in their environment
elevation	noun	標高	height above a given level, especially sea level
above sea level	noun	海抜	
Mesozoic era	noun	中生代	
geologic time scale	noun	地質時代	
event	noun	出来事、事象	a thing that happens, especially something important

【Vocabulary 2】

本文 (Geological History of Earth)			
landslide	noun	地滑り	the sliding down of a mass of earth or rock from a mountain or cliff
fault	noun	断層	an extended break in a rock formation
continental drift	noun	大陸移動説	
supercontinent	noun	超大陸	
Pangaea	noun	パンゲア大陸	
distribution	noun	分布	
terrestrial heat flow	noun	地殻熱流量	
seafloor spreading	noun	海洋底拡大説	
plate tectonics	noun	ﾌﾟﾚｰﾄﾃｸﾄﾆｸｽ	
massive	adj	どっしりした	
tectonic plates	noun	(地殻)構造プレート	
interact	verb	互いに影響し合う	to have an effect on each other
plate boundaries	noun	プレート境界	
apart	adv	（から）離れて	
divergent boundaries.	noun	発散境界	
seafloor	noun	海底	
ocean ridge	noun	海嶺	
erupt	verb	噴火する	forcefully eject lava, rocks, ash, or gases
pillow lava	noun	枕状溶岩	
uppermost	adj	最も外部の	
lithosphere	noun	リソスフェア	
convergent boundaries	noun	収束境界	
oceanic plate	noun	海洋プレート	
sink	verb	沈み込む	to go down below the surface or towards the bottom of a liquid
dense	adj	密度の高い	closely compacted in substance
continental plate	noun	大陸プレート	
depression	noun	陥没、窪地	a part of a surface that is lower than the parts around it
trench	noun	海溝	a long, narrow, deep depression in the ocean bed
mountain range	noun	山脈	
transform fault	noun	トランスフォーム断層	
hot spot	noun	ホットスポット	パイプ状に常にマグマが上昇してくる地点
mantle plumes	noun	マントルプルーム	
pacific plate	noun	太平洋プレート	
trail	noun	列、跡	
seamount	noun	海山、海底火山	a submarine mountain
the Pacific Ocean	noun	太平洋	
授業			
coral reef	noun	サンゴ礁	
alpine plant	noun	高山植物	
coal	noun	石炭	a hard black rock consisting mainly of carbonized plant matter and used as fuel
pressure	noun	圧力	

■ Formation of Hokkaido - part 1 -

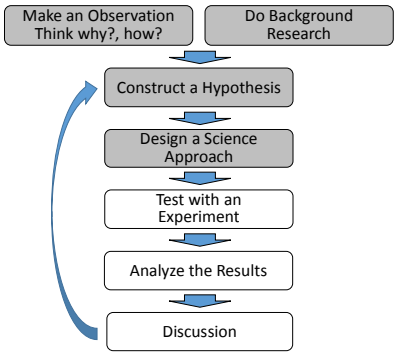
English Science

Words learned through English Science

Point!

Construct a Hypothesis -the use of logical thinking-

Scientific Approach



●課題を解決するための科学的手法の１つに、「実験、観察、調査等の結果に基づき考察すること」があります。仮説を検証するには、実験を行い、その結果を論理的に考察して検証を行います。しかし、過去の事実や未来に予想される事象のように、実験によって結論を直接に観察することができない場合があります。そのような場合は、

1. 事実を説明できる仮説を立てて、
2. その仮説から観察可能な事象を予想し、
3. 調査に出かけ、観察事象を収集する。
4. その観察事象（結果）が仮説に合うか合わないかを調べ、仮説を検証します。

重要なことは、事実に基づいていることと、論理の飛躍がないことです。

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」を行ってみましょう。

It's Your Turn Activities with TA

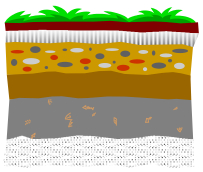
Useful Expression.

be formed：出来る、形成される、誕生する

【Role play】

A: Where is Ozone formed?
How is Ozone formed?
Where are sedimentary rocks formed?
How are sedimentary rocks formed?

B: Ozone is formed in the atmosphere.
Ozone is formed by chemical reactions.
Sedimentary rocks are formed under the sea.
Sedimentary rocks are formed by the accumulation of sediments.

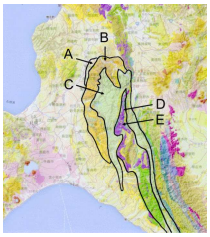
	Where?	How?
	ozone	sedimentary rocks
		
	atmosphere	under the sea
	chemical reactions	accumulation of sediments

0 Initial Facts You Found (Kirigishi-yama -1,066m-)

※ 1 Ma: 1 million years ago

Observation 1

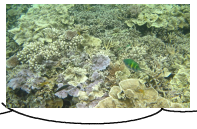
Observe the samples collected from point D and get information from TAs so that you can fill the space below.



出典：20 万分の 1
日本シームレス地
質図データベース

[**Fossils of Cretaceous** 白亜紀]

1. Collecting Place : _____
2. Elevation: _____ m (**Kirigishi-yama**)
3. Fossils name

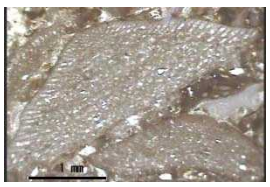
【TAs Question】	【Your Answer】
Q1.	→ reply　Yes or No
Q2.	→ reply　fossil 
Q3.	→ reply　we see them 沖縄　グアム　サイパン

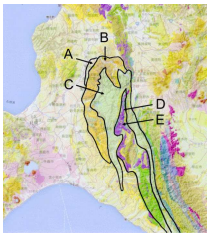
The rock of Kirigishi-yama

- The rock which makes Kirigishi-yama includes (　　).
- Coral reefs are found in (　　).

Observation 2

Observe the samples collected from point D and get information from TAs so that you can fill the space below.





出典：20 万分の 1
日本シームレス地
質図データベース

[**Fossils of Cretaceous** 白亜紀]

1. Collecting Place : _____
2. Elevation: _____ m (**Kirigishi-yama**)
3. Fossils name

【TAs Question】	【Your Answer】
Q1.	→ reply　Yes or No

Q2.

→ reply Yes or No

Q3.

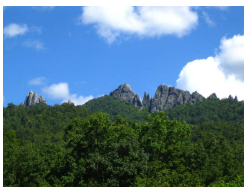
→ reply Yes or No

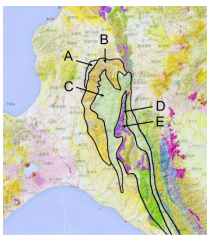
The rock of Kirigishi-yama

- The rock which makes Kirigishi-yama includes ( ).
- Orbitolina is an index fossil of ( ) period ( ).

Experiment 1

Observe the samples collected from point D and get information from TAs so that you can fill the space below.





出典：20 万分の 1 日本シームレス地質図データベース

[**Fossils of Cretaceous** 白亜紀]

1. Collecting Place : _____
2. Elevation: _____ m (**Kirigishi-yama)**
3. Fossils name

【TAs Question】

Q1.

Q2.

【Your Answer】

→ reply Yes or No

→ reply Yes or No

Chemical composition: 化学組成

_____ + 2HCl → $CaCl_2 + H_2O + CO_2 \uparrow$

dissolve: 溶ける

→ reply

hydrochloric acid: 塩酸　limestone: 石灰岩

Calcium carbonate: 炭酸カルシウム($CaCO_3$)

The rock of Kirigishi-yama

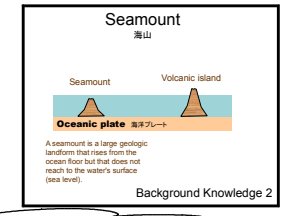
- Kirigishi-yama is made up of ( ) .

Background Knowledge 1

Let's learn about plate techtonics from TA.

【TAs Question】

【Your Answer】



Q1. → reply Yes or No

Q2. → reply Yes or No

Q3. → reply west collide

Background Knowledge 1

・ The Pacific Plate is ( ) to the northwest.

Background Knowledge 2

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

ビデオの情報を
素早くメモ！

【TAs Question】

【Your Answer】

Q1. → reply Yes or No

Q2. → reply Yes or No

Q3. → reply

Video
JAMSTEC（海洋研究開発機構）
有人潜水調査船「しんかい 6500」
インド洋海嶺（深度 3500m）
21.Jan.2016

It is

Q4.

→ reply

Video
NOAA（アメリカ海洋大気庁）
Pacific Ocean between Samoa, Fiji and Tonga（深度 1200m）
May.2009

The name is

Background Knowledge 2

・ (　　) is formed when magma erupts and cools rapidly at the deep-ocean seafloor.

・ Ocean floor is made of lava called “ (　　) ”.

Activity 1　Use the map to answer the questions below.

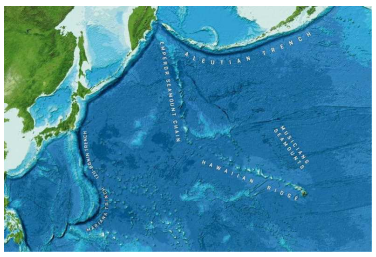
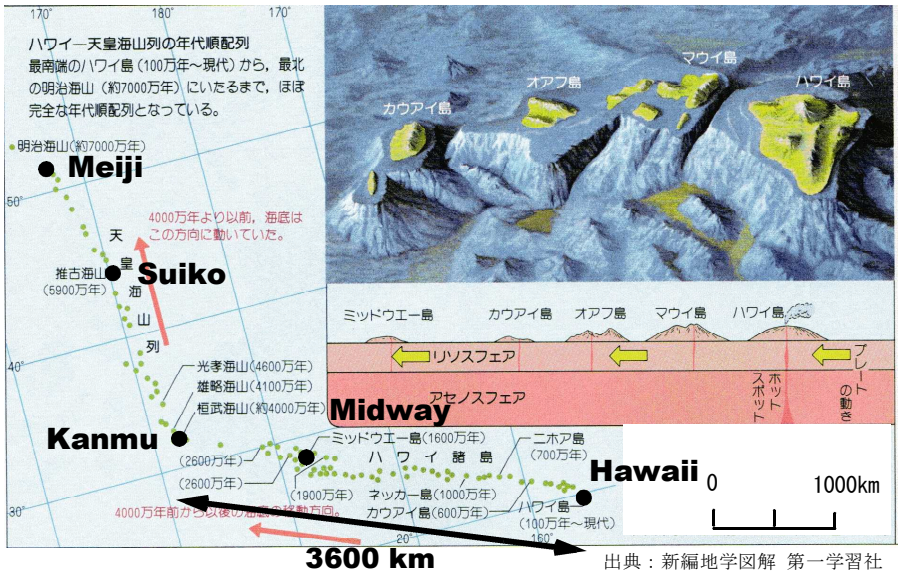


Image reproduced from the GEBCO world map 2014, www.gebco.net



出典：新編地学図解 第一学習社

Q1. Calculate the average speed of the Pacific plate over the last 40 million years.

・Distance between Kanmu-kaizan and the Hawaiian island：　　km

・Time interval between the eruptions of the two volcanoes：　　million years

average speed ＝　　cm/year

Q2. Using the tracing paper, demonstrate how the Hawaiian-Emperor seamount chain was formed.

Q3. Where do you think Kanmu Seamount will be 40 million years from now?

1 Construct a Hypothesis which is able to explain the cause of the initial fact

The scientific method starts when you ask a question about what you have observed. Now you want to find out how Kirigishi-yama was formed. You ask the following question about the initial fact.

Initial Question ： Why is Kirigishi-yama made up of limestone which include fossil corals of 100 million years ago?

Aim of your research : To clarify the formation process of Kirigishi-yama.

Activity 2

Imagine the environment of the era when Kirigishi-yama was formed. In groups, discuss and construct a hypothesis which is able to explain the initial fact.

Initial Facts you Found	The Knowledge You Gained
● **Observation 1&2** ・ The rock of Kirigishi-yama includes ( ) and ( ) of ( ) period ● **Experiment 1** ・ Kirigishi-yama is made up of ( )	● **Background Knowledge 1** ・ The Pacific Plate have been ( ) to the northwest from Cretaceous period. ● **Background Knowledge 2** ・ Ocean floor is made of lava called " ( ) ".

• Create a story which is able to explain why Kirigishi-yama (a coral island) is in the center of Hokkaido.

Hypothesis

Hypothesis:

2 Predict Observable Facts from hypothesis

Although most scientific research conduct experiments in controlled laboratory settings to test hypotheses, historical hypotheses about particular past events such as continental drift, the giant-impact hypothesis and the big bang origin of the universe, etc. are not testable in the laboratory because the time frame required is too long and the scale required is too large. In this case, the best that can be done is to predict observable facts logically which are derived from your hypothesis. Then search the observable facts in the natural world in order to test and evaluate your hypothesis.

Activity 3

Now you construct a hypothesis. Discuss logically, if your hypothesis is true, then what will you discover around Kirigishi-yama? This is your prediction.

Hypothesis : A coral reef of 100 million years ago rose up and became Kirigishi-yama.

Logical Thinking

Prediction :

_____ will be found around Kirigishi-yama.
_____ will be found around Kirigishi-yama.
_____ will be found around Kirigishi-yama.

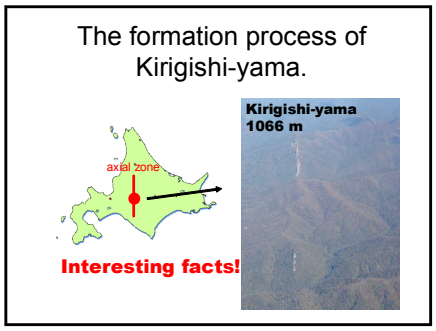
3 Investigation

Activity 4

You are going to Mikasa, Ashibetsu and Takikawa in order to find positive evidence to support your hypothesis. Before you go to do a survey, create an ArcGIS Survey123 Form in a Browser in order to visualize your findings on a map.

【Presentation Exercise】 Let's try to have a presentation using the following slides and script.

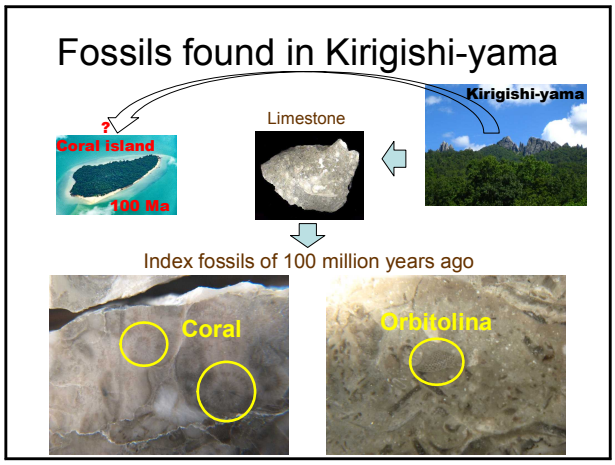
Introduction



- My name is .
- Now, I'm going to talk about the formation process of Kirigishi-yama.
- Kirigishi-yama is located in the axial zone of central Hokkaido.
- I found interesting facts at Kirigishi-yama.
- First, I'll explain it to you.

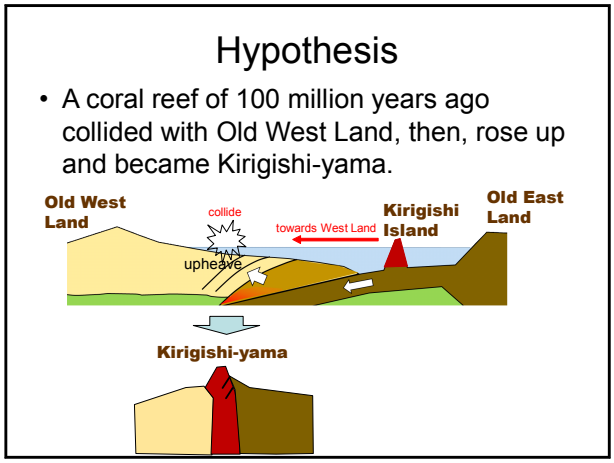
axial zone: 中軸帯

Body 1



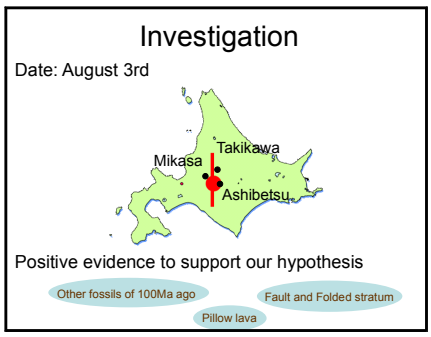
- Kirigishi-yama is made up of limestone which includes corals and orbitolina of 100 million years ago shown in this pictures.
- But, don't you think it's strange?
- Why is a coral island formed 100 million years ago now found at the top of the mountain?

Body 2



- Then, I built up the following hypothesis based on our findings.
- There was Kirigishi Island between two lands; Old West Land and Old East Land.
- Kirigishi and Old East Land moved closer towards Old West Land.
- First, Kirigishi Island collided with Old West Land and then Old East Land collided with them.

Conclusion



- August 3rd, we are going to Mikasa, in order to find positive evidence to support our hypothesis.
- Thank you for listening.

■ Formation of Hokkaido - part 2 -

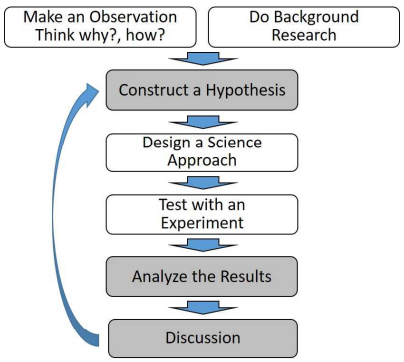
English Science

Words learned through English Science

Point!

Discussion –the use of logical/integrating thinking–

Scientific Approach



●課題を解決するための科学的手法の１つに、「実験、観察、調査等の結果に基づき考察すること」があります。仮説を検証するには、実験を行い、その結果を論理的に考察して検証を行います。しかし、過去の事実や未来に予想される事象のように、実験によって結論を直接に観察することができない場合があります。そのような場合は、

1. 事実を説明できる仮説を立てて、
2. その仮説から観察可能な事象を予想し、
3. 調査に出かけ、観察事象を収集する。
4. その観察事象（結果）が仮説に合うか合わないかを調べ、仮説を検証します。

重要なことは、事実に基づいていることと、論理の飛躍がないことです。

ここでは、いくつもの観察事象を根拠として、論理的に結論を導くための推論過程（帰納的に検証する過程）に着目して、仮説を検証して見ましょう。

Integrated thinking: 統合的に考える

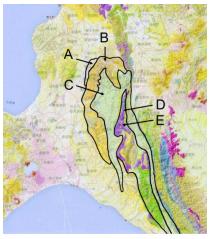
3 Investigation & Results

Now you want to find positive evidence to support that the center of Hokkaido rose up from the ocean 100 million years ago. In groups, investigate various fossils and rocks of the center of Hokkaido and consider the environment of each place in the following geologic ages. TAs will help you so that you can fill the space below.

Investigation 1 (Along Sorachi River)

[**Fossils of Tertiary Paleogene** 古第三紀]

1. Collecting Place : _____
2. Elevation: _____ m
3. Fossils name



Fossil	Geologic age	Habitat
Coal bed	Tertiary Paleogene (40 Ma)	Deep sea, Shallow sea, Wetland, Temperate land
Oyster	the same as above	Deep sea, Shallow sea, Wetland, Temperate land
Fossil plant	the same as above	Deep sea, Shallow sea, Wetland, Temperate land

【TAs Question】

Q1.

Q2.

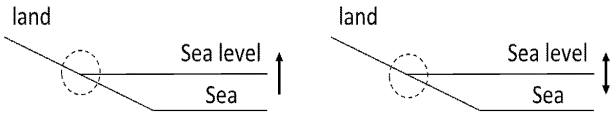
【Your Answer】

→ reply

→ reply

this
charcoal coal

charcoal coal
burned wood fossil fuel



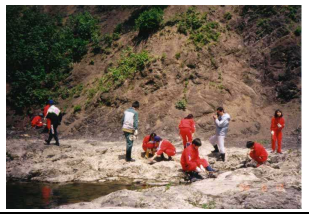
Describing Events - Investigation 1 -

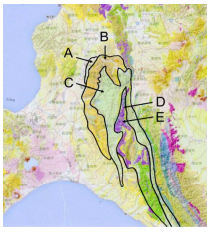
- Fossils of _____ and fossil _____ are found along Sorachi river.
- Oysters lived in shallow _____ and the plants became fossil plants that lived on _____ 40 million years ago.

Investigation 2 (Mountainside of the Yubari Mountains)

[**Fossils of Cretaceous** 白亜紀]

1. Collecting Place : _____
2. Elevation: _____ m
3. Fossils name





Fossil	Geologic age	Habitat
Ammonite	Cretaceous (100 Ma)	Deep sea, Shallow sea, Wetland, Temperate land
Inoceramus	the same as above	Deep sea, Shallow sea, Wetland, Temperate land

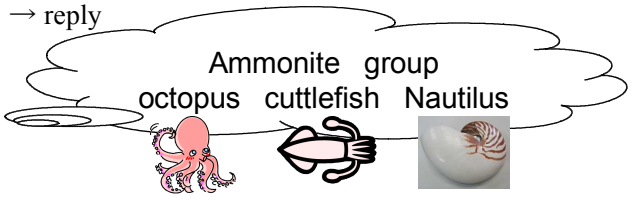
【TAs Question】

Q1.

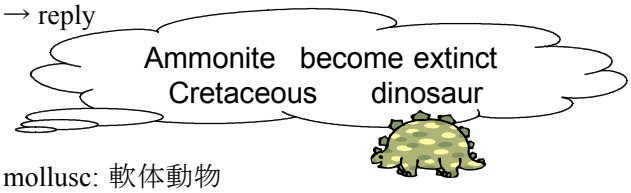
Q2.

【Your Answer】

→ reply



→ reply



mollusc: 軟体動物
nautilus: オウムガイ　dinosaur: 恐竜

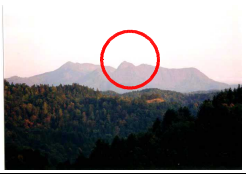
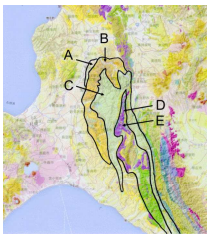
Describing Events - Investigation 2 -

- _____ and _____ are found around the mountainside of the Yubari Mountains.
- They lived in a shallow _____ _____ _____ years ago.

Investigation 3 (Mae-dake -1,501m-)

[Rocks of the seafloor]

1. Collecting Place : _____
2. Elevation: _____ m
3. Rocks name

Rock	Geologic age	Environment
Pillow lava	unknown	Erupted (on the Land, on the seafloor)

【TAs Question】

This is a daily English conversation.

Q1.

Q2.

Ok, from now, it's time to study.

Q3.

Q4.

【Your Answer】

JAMSTEC 海洋研究開発機構
(Japan Agency for Marine-Earth Science and Technology)

→ reply

Yes or No
1月 冬休み

→ reply

＊ビデオの情報を素早くメモ！

NOAA アメリカ海洋大気庁
(National Oceanic and Atmospheric Administration)

→ reply

Yes or No

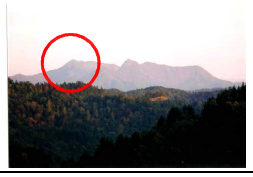
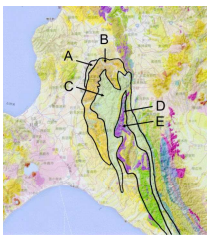
Describing Events - Investigation 3 -

- The rock which makes Mae-dake is _____ _____ .
- Pillow lava is formed when magma erupts at the _____ _____ .

Investigation 4 (Yubari-dake -1,668m-)

[Rocks of Tertiary Paleogene 古第三紀**]**

1. Collecting Place : _____
2. Elevation: _____ m
3. Rocks name

Rock	Geologic age	Environment
Metamorphic rock	Tertiary Paleogene (40 Ma)	

【TAs Question】

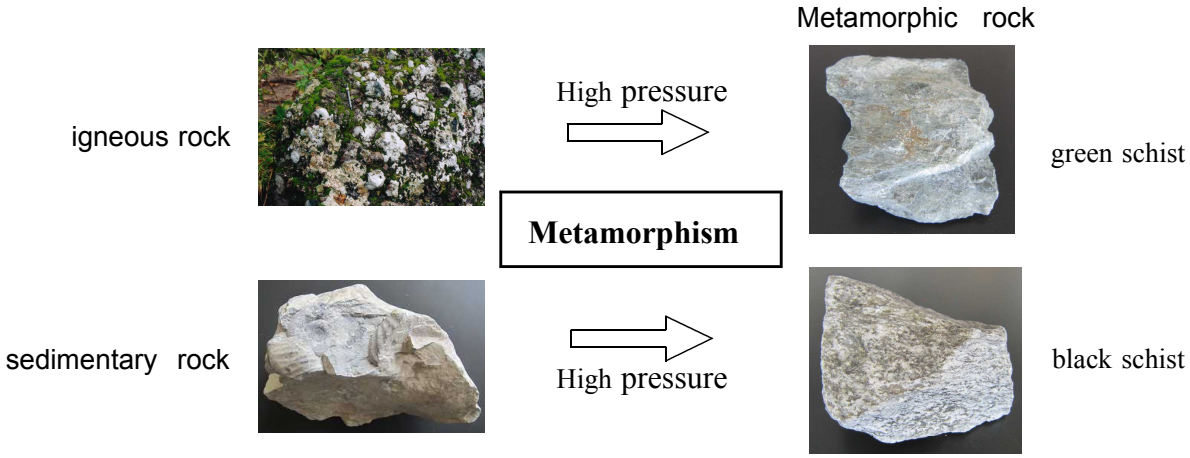
Q1.

【Your Answer】

→ reply

this rock　green
see　layering 層構造

metamorphic rock: 変成岩
metamorphism: 変成作用
pressure: 圧力
igneous rock: 火成岩
sedimentary rock: 堆積岩



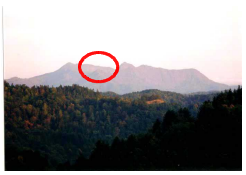
Describing Events - Investigation 4 -

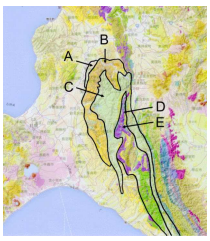
- The rock which makes Yubari-dake is _____ rock.
- Metamorphic rocks are rocks that have changed form due to high _____.

Investigation 5 (The main ridge of Yubari-dake)

[Alpine plants]

1. Collecting Place : _____
2. Elevation: _____ m
3. Plants name





Plants	Environment
Yubari kozakura (Primula yuparensis) 	Serpentinite ( )
Yubarisou (Lagotis takedana) 	Serpentinite ( )
sisobakisumire (Viola yubariana) 	Serpentinite ( )

高山植物写真（出典）：ユウパリコザクラの会. http://yuparikozakura.org/?page_id=39（accessed 2018-07-20）.

【TAs Answer】

- Look at this picture. These are alpine plants living only in this area. These plants are called endemic species.

Students :

⇒

Students :

⇒

【Your Question】 ここでは TA に質問してみよう！

endemic species: 固有種　　serpentinite: 蛇紋岩

← Q1.

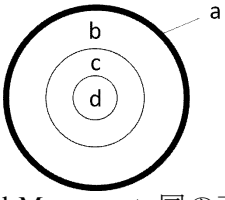
どうして、ここにだけ生息しているの？

Why　these plants　live　only

← Q2.

蛇紋岩って、どんな石ですか？

What　serpentinite



The earth

National Natural Monument: 国の天然記念物

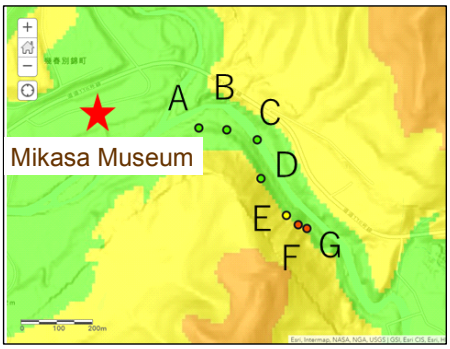
Describing Events - Investigation 5 -

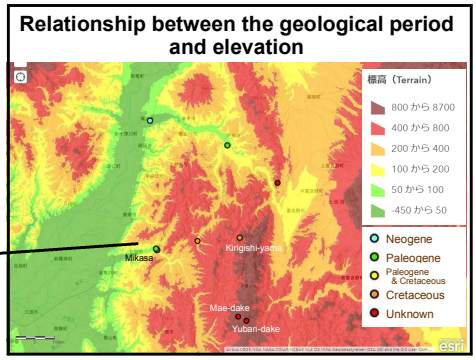
- Endemic _____ _____ that are able to grow in the soil made from serpentinite are living around the main ridge of Yubari-dake.
- Serpentinite is a rock originated from the upper _____.

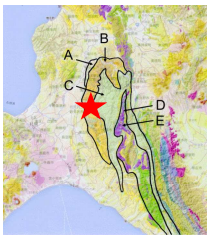
Investigation 6 (Your field trip to Mikasa, Ashibetsu and Takikawa)

Activity 1

The followings are your findings and maps you made using GIS after your survey. Classify your findings to the facts you predicted and you did not predict from your hypothesis.







Describing Events - Investigation 5 -

- A vertical rock strata is found at point A.
- A coal-bed is found at point B.
- A vertical rock strata is found at point C.
- A coal-bed is found at point D.
- An unconformity between Cretaceous and Paleogene strata is found at point E.
- A vertical rock strata is found at point F.
- A fault is found at point G.

The facts you predicted	The facts you did not predict

4 Discussion to test hypothesis

Now you investigated the facts and existence of new facts that follow from the hypothesis. Then, the last step is discussion.

Discuss carefully and logically whether many pieces of evidence you found support or oppose your hypothesis and combine these to form a logical explanation. All the available information can be combined into a logical answer.

The goal of science is to explain events of the natural world. This inductive reasoning; accumulation of evidence which support the hypothesis, can strengthen the probability of a more general conclusion, which explains the natural world.

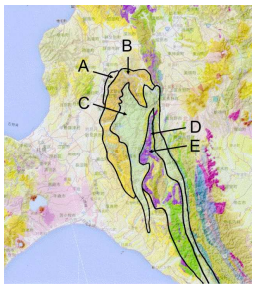
Thinking Critically

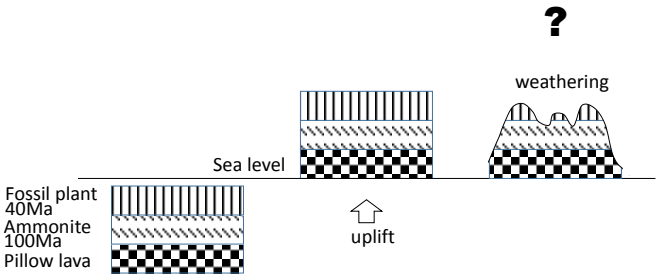
Exercise 1

Which elevation is higher; the area where younger fossils are found or the area where older fossils are found. And let's think of the reason.

B
Elevation: 40 ～ 100m
Fossil plant, Coal bed

C,D,E
Elevation: 350 ～ 1500m
Ammonite, Pillow lava,





From observations,

the elevation of the area where (older fossils, younger fossils) are found is higher than the area where (older fossils, younger fossils) are found.

Interpreting Events

Exercise 2

Now you found new facts around Kirigishi-yama, then explain what this means logically. The first one has been done for you.

Facts you found - Investigation 1 -

- Fossils of oysters and fossil plants are found along Sorachi river.
- Oysters lived in shallow sea and the plants became fossil plants that lived on land 40 million years ago.

⇩ **Logical Thinking**

- 40 million years ago, this area became **the sea** and **the land** alternating because its sea level kept rising and falling several times.

Making Predictions & Evaluating Results

Exercise 3

Why did a coral island form 100 million years ago at the center of Hokkaido? Explain how Kirigishi-yama (or Hokkaido Island) and Yubari mountain range were formed by combining all the facts you found. This reasoning can strengthen the probability of a more general conclusion.

Thinking Critically & Evaluating Results

Exercise 4

The fossils and geological events found in Investigation 1 and 6 are the ones of Tertiary Paleogene era. In groups, discuss carefully and logically whether the evidence you found in Investigation 1 and 6 supports or opposes your hypothesis.

[Exercise 2 & Exercise 3]

Rocks

Mae-dake is formed by pillow lava.

⇩

Mae-dake was a part of the _____ _____.

Yubari-dake is formed by metamorphic rocks.

⇩

When Yubari-dake was formed, a large amount of _____ was applied on the rocks.

Facts **Integrative Thinking**

Plate Tectonics

A series of seamount chain stretches across the Pacific from Hawaii to Kamchatka.

⇩

The Pacific Plate was _____ to the northwest.

When and How was Hokkaido formed?

Alpine plants

The peculiar alpine plants are growing on serpentinites around the main ridge of Yubari-dake.

⇩

The main ridge of Yubari-dake was a part of the upper _____.

Fossils

Orbitolina and corals are found in the Kirigishi-yama.

⇩

100 million years ago, Kirigishi-yama was a _____ _____.

Ammonites are found around the mountainside of the Yubari Mountains.

⇩

100 million years ago, this area was shallow _____.

green schist 

black schist 

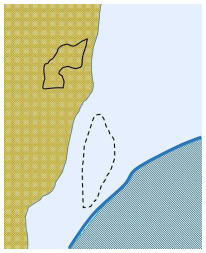
pressure

⇦

Metamorphism

 igneous rock

 sedimentary rock



Drawing Conclusions

Exercise 5

Write down the appropriate words to complete the sentences.

The following were the main findings: (a) a coral island formed 100 million years ago and an oceanic plate both collided with Old Hokkaido Land and rose up with upper mantle and (b) later, the coral island became the _____, some parts of oceanic plate became _____ _____, _____ and _____, and the upper mantle became _____ zone which are there in between Yubari-dake and Mae-dake.

However, the shape of Old Hokkaido Land and the direction of the collision are still unclear.

Additional studies related to the formation of Hidaka mountain is strongly suggested.

Paradigm shift

There were two major theories to explain how mountains were formed in the 1960s.

One was the geosyncline theory of mountain formation. There are two stages to the formation of a mountain in this theory; subsidence and uplift. First, there is a place that sinks over a long time on the seafloor near the land (though the reason it sinks is not understood) where vast amounts of sediment which is over 10,000 m accumulates, and the deep part of the sediment becomes a metamorphic rock because of high temperature and high pressure. Then, this area changes to uplift to form a mountain accompanied by fold and fault. That is to say, this is a theory that states a mountain is formed by the vertical movement

The other is the theory of plate tectonics which you know well. That is to say, this is a theory that a mountain is formed by the horizontal movement of the earth's surface.

A huge debate whether this plate tectonics theory is true or not has been sparked, which has divided the academic community into those for or against the theory, when it was first brought to Japan. I still remember that I learned the geosyncline theory in university in the early 1980s. In this topic of the lesson, it was concluded simply that, Kirigishi Island was scraped off the oceanic plate and then uplifted to be added to form land areas of Hokkaido with the assumption that plate tectonics have been widely accepted. However, real science research done around this time was not as simple as this. To change this paradigm, it requires huge debate and energy.

What brings an end to the argument is the accumulation of scientific data. The starting point of plate tectonics is the theory of continental drift proposed by Alfred Wegener in 1912. However, continental drift was not readily accepted because there was no force known that would allow continents to move. It was gradually accepted as corroborating scientific data; e.g. submarine topography, terrestrial heat flow and paleomagnetism, was collected and as seismology were developed, the geosyncline theory has been replaced as plate tectonics a half century later. Today, GPS data can directly show plates are moving horizontally.

Understanding of solid-earth has drastically changed over the last hundred years. Especially, the 1980's studies of seismic tomography, a kind of CT scan using seismic wave, provided a new view of the Earth's interior, showing that a large-scale upwelling of mantle flow appears as a passive response of cold plume. Due to the remarkable achievements in technology, the dynamic motion in the Earth's interior is rapidly becoming clearer.

However, a lot is still unknown in this field. Would you like to take part in scientific research and make a paradigm shift in science?

geosyncline: 地向斜　subsidence: 沈降　the theory of continental drift: 大陸移動説
submarine topography: 海底地形　terrestrial heat flow: 地殻熱流量
paleomagnetism: 古地磁気学　seismology: 地震学
seismic tomography: 地震波トモグラフィー

考察(Discussion)で使う英語表現２

科学研究の最後には、結論として、研究結果を客観的に評価し、発見したことを明確かつ論理的に述べます。
結論では、次のようなことを述べます。
・仮説への答え：研究から得られた主要な結果のみを示す。
・研究でわかったこと：過去の報告と異なる結果や予想外の結果は強調する。
・残された課題（限界）：解決できなかったことを示す。
・発展の可能性：自分の研究の成果を、今後どのような方面に生かすことができるかを示唆します。
得られた結果を詳しく調べていくと、面白い着想や発見に繋がることもあります。また、得られた結果（知識）が他の分野への応用に繋がることもあります。

１　仮説を支持するとき

confirm, support, give strength to, demonstrate, show,
There is enough evidence to show that ..., The hypothesis in the present study was statistically confirmed.
例 This evidence / result appears to confirm / support / give strength to the hypothesis that ... .

２　仮説を否定するとき

contradict, do not support, make it unlikely(that))
例 These results contradict / do not support the hypothesis that ... .

３　限界をのべるとき

It should be noted that ... because ..., A limitation of the present study was that ...

４　今後の研究に提案をするとき

Future studies will need to investigate ...,

５　原因を議論するとき

Therefore, Thus, As a result, Because, Because of, As a result of, lead to influence, play a role in

６　結論(Conclusion)で使う表現

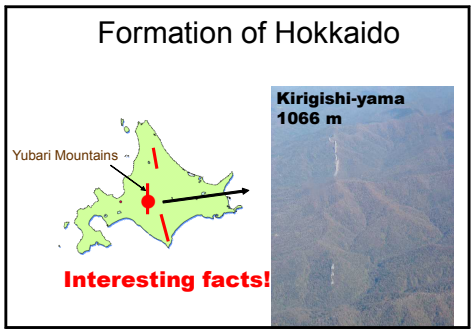
These results lead to the conclusion that ..., These results demonstrate that ...,
The following were the main findings: 1. ...

Exercise 1　Use the phrases above, write down the sentences which support the hypothesis.

There is enough evidence to show that（　　）.
This evidence appears to support the hypothesis that (
　　).

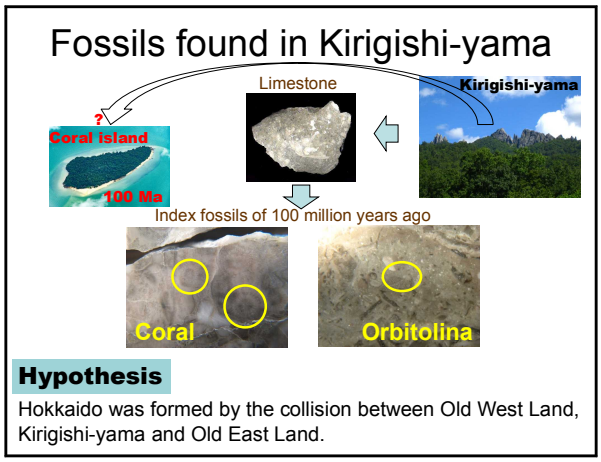
【Presentation Exercise】 Let's try to have a presentation using the following slides and script.

Introduction



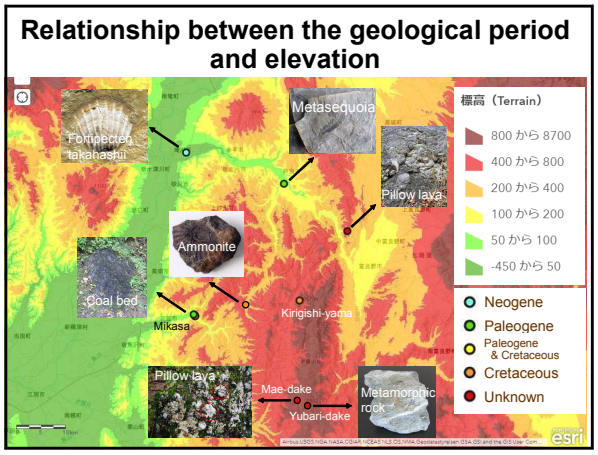
- My name is .
- Now, I'm going to talk about the formation of Hokkaido.
- Do you think Hokkaido Island existed long ago?
- OK, I'll explain it to you.
- To start with, look at this image. This is Kirigishi-yama.

Body 1



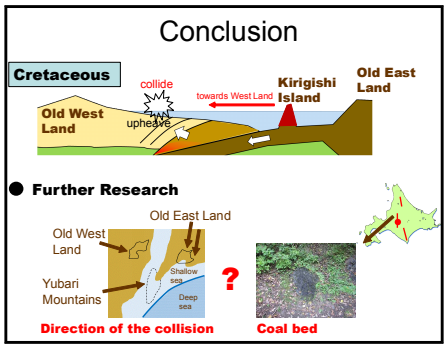
- Kirigishi-yama is made up of limestone which includes corals and orbitolina of 100 million years ago shown in this pictures.
- But, don't you think it's strange?
- Why is a coral island formed 100 million years ago now found at the top of the mountain?
- Then we constructed a hypothesis shown in this slide.
- If our hypothesis is true, we can find fossils of the Cretaceous period, and rocks which shows there was pressure in this region.
- Then, we went out to investigate in order to test our hypothesis.

Body 2



- Look at this map. These are our findings.
- For example, we found Ammonites and pillow lava which shows there was a seafloor.
- Further, we found metamorphic rock at Yubari-dake and fault at Mikasa which shows a large amount of pressure was applied on the rocks.

Conclusion



- In conclusion, this evidence appear to support our hypothesis.
- However, the direction of the collision and why there was a coal bed around the foot of Yubari mountains are still unclear.
- More research is needed to answer these new questions.
- Thank you for listening.

Exercise 1

The above are the slides and scripts of students presentation about their geological research. What point does the presenter want to tell the most? Choose the most suitable statement from the following ①～④.

① They found fossil corals at the top of Kirigishi-yama which is very strange.
② Their finding of coal bed around the foot of Yubari mountains has raised important questions that their hypothesis is not true.
③ Next, we are going to investigate around Yubari mountains in order to find the answer why a coal bed was found around it.
④ Their finding of Ammonites and metamorphic rock provided additional evidence that Hokkaido was formed by the collision of two lands.

Black Diamond

Coal is an accumulation of ancient plant material that, once buried deep underground for a long time, and because of heat and pressure, is converted into carbon-based material. Coal is an inevitable fuel for power generation plants as well as materials to make iron. This is called "Black Diamond" because it was used as invaluable energy resource in Japan.

The coal industry has promoted the modernization of Japan for one century. The Sorachi region, at present, is facing the challenge of an aging and declining population. However, there were over 100 coal mines and more than 800,000 people lived there during its mining heyday of the 1960s. The region we visited for the geological survey has boasted the largest coal production in the country. The Horonai Railway was constructed between Mikasa and Otaru for the first time in Hokkaido, in order to transport coal for supporting the industrialization of Japan. Then railways were extended across various parts of Hokkaido which supported the development of Hokkaido. On the other hand, working in an underground coal mine faces the risk of some danger such as coal-dust explosion. We must never forget that, in this region, a lot of coal mine workers supported Japan's postwar economic growth until the last Hokutan Sorachi Coal Mining in Utashinai closed in 1995 due to the shift of national energy policies from coal to oil.