Explanation material of the Nationwide Map of “Scientific Features” relevant for Geological Disposal

Ministry of Economy, Trade and Industry
Agency for Natural Resources and Energy

Introduction

1. Purpose of this document

- The Nationwide Map of “Scientific Features” relevant for Geological Disposal overviews relevant factors that need to be considered when selecting a repository site and their distribution throughout Japan. The Japanese government plans to utilize this map for communication activities to enhance public understanding.
- In preparation for the Map of such scientific characteristics, experts discussed what requirements/criteria should be set at the Council of the Ministry of Economy, Trade and Industry.
- The outcome of these discussions are summarized in the “Summary of Requirements and Criteria for Nationwide Map of Scientific Features for Geological Disposal (compiled by the Geological Disposal Technology Working Group)” (April 2017). The Nationwide Map of “Scientific Features” relevant for Geological Disposal was drawn up on the basis of these requirements/criteria. This document explains the points to be considered, etc.

2. Points to be considered regarding the Map

- The scale of the Nationwide Map of “Scientific Features” relevant for Geological Disposal is 1/2,000,000, reflecting the smallest scale of the source data. Note that the requirements and criteria used for creating the Map do not conclusively denote specific scientific features. In addition, the scale of the Map does not allow accuracy of more than 1/2,000,000. Thus, there is a limit to the accuracy of the boundaries of scientific features: the Map also shows the boundary of the municipalities, but the relative position with the segment boundaries of scientific features has inherent inaccuracies.
- The Nationwide Map of “Scientific Features” relevant for Geological Disposal does not directly indicate whether a specific area has suitable scientific features for deciding a repository site. In order to confirm the suitability of the site, the Nuclear Waste Management Organization of Japan (NUMO) needs to conduct site investigation and evaluate these scientific characteristics in detail.

3. Contact us

The Nationwide Map of “Scientific Features” relevant for Geological Disposal and associated explanation materials are available on the following sites.

https://www.enecho.meti.go.jp/en/category/electricity_and_gas/nuclear/rwm/
https://www.numo.or.jp/en/jigyou/

Radioactive Waste Management Policy Division, Electricity and Gas Industry Department,
Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry

Contents

Nationwide Map of “Scientific Features” relevant for Geological Disposal

○ Scientific Features and Classification of Areas identified on the Map

1 . Classification of areas in terms of scientific features

- The application of criteria by the Geological Disposal Technology Working Group for identifying features and nationwide classification of areas is illustrated in the figure below. As shown in this figure, areas “assumed to be favorable,” with a relatively high probability that favorable features for geological disposal could be confirmed, are classified as candidates for future site-specific investigations.
- The Nationwide Map of “Scientific Feature” relevant for Geological Disposal does not, however, directly indicate whether a specific area has suitable scientific features for constructing a geological repository. Stepwise investigation and careful evaluation of candidate sites according to the Final Disposal Act are essential for selecting a final repository site; this takes into account various other important features that are not included in the Map.

Criteria to identify unfavorable features
Vicinity of volcanoes
Vicinity of active faults
Significant uplift/erosion
High geothermal gradient
etc.
Existence of mineral resources
If any one is applicable
If applicable
If none is applicable
Criteria to identify preferable features
Relatively short distance from coastline (including sub-seabed and islands)
If applicable
Classification of areas
Assumed to be unfavorable
from the viewpoint of long-term stability of the deep geological environment
from the viewpoint of the risk of future inadvertent human intrusion
Assumed to be favorable
Assumed to be preferable also from the viewpoint of safe waste transportation

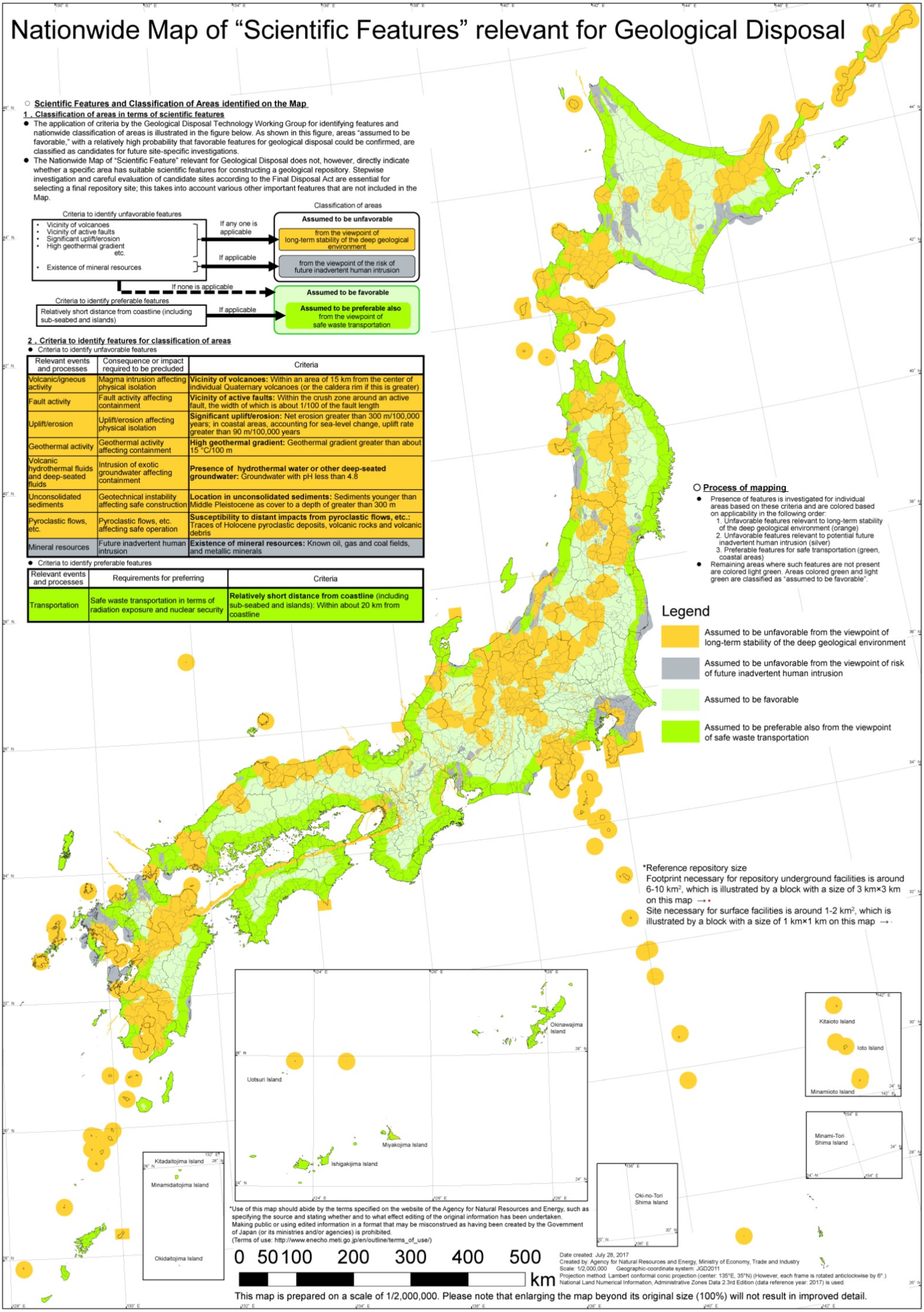
2 . Criteria to identify features for classification of areas

- Criteria to identify unfavorable features

Relevant events and processes	Consequence or impact required to be precluded	Criteria
Volcanic/igneous activity	Magma intrusion affecting physical isolation	**Vicinity of volcanoes:** Within an area of 15 km from the center of individual Quaternary volcanoes (or the caldera rim if this is greater)
Fault activity	Fault activity affecting containment	**Vicinity of active faults:** Within the crush zone around an active fault, the width of which is about 1/100 of the fault length
Uplift/erosion	Uplift/erosion affecting physical isolation	**Significant uplift/erosion:** Net erosion greater than 300 m/100,000 years; in coastal areas, accounting for sea-level change, uplift rate greater than 90 m/100,000 years
Geothermal activity	Geothermal activity affecting containment	**High geothermal gradient:** Geothermal gradient greater than about 15 °C/100 m
Volcanic hydrothermal fluids and deep-seated fluids	Intrusion of exotic groundwater affecting containment	**Presence of hydrothermal water or other deep-seated groundwater:** Groundwater with pH less than 4.8
Unconsolidated sediments	Geotechnical instability affecting safe construction	**Location in unconsolidated sediments:** Sediments younger than Middle Pleistocene as cover to a depth of greater than 300 m
Pyroclastic flows, etc.	Pyroclastic flows, etc. affecting safe operation	**Susceptibility to distant impacts from pyroclastic flows, etc.:** Traces of Holocene pyroclastic deposits, volcanic rocks and volcanic debris
Mineral resources	Future inadvertent human intrusion	**Existence of mineral resources:** Known oil, gas and coal fields, and metallic minerals

- Criteria to identify preferable features

Relevant events and processes	Requirements for preferring	Criteria
Transportation	Safe waste transportation in terms of radiation exposure and nuclear security	**Relatively short distance from coastline** (including sub-seabed and islands): Within about 20 km from coastline



○ Process of mapping

- Presence of features is investigated for individual areas based on these criteria and are colored based on applicability in the following order:
  1. Unfavorable features relevant to long-term stability of the deep geological environment (orange)
  2. Unfavorable features relevant to potential future inadvertent human intrusion (silver)
  3. Preferable features for safe transportation (green, coastal areas)
- Remaining areas where such features are not present are colored light green. Areas colored green and light green are classified as “assumed to be favorable”.

Legend

- Assumed to be unfavorable from the viewpoint of long-term stability of the deep geological environment
- Assumed to be unfavorable from the viewpoint of risk of future inadvertent human intrusion
- Assumed to be favorable
- Assumed to be preferable also from the viewpoint of safe waste transportation

*Reference repository size
Footprint necessary for repository underground facilities is around 6-10 km², which is illustrated by a block with a size of 3 km×3 km on this map →
Site necessary for surface facilities is around 1-2 km², which is illustrated by a block with a size of 1 km×1 km on this map →

Date created: July 28, 2017
Created by: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry
Scale: 1/2,000,000 Geographic-coordinate system: JGD2011
Projection method: Lambert conformal conic projection (center: 135°E, 35°N) (However, each frame is rotated anticlockwise by 6°.)
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○ Scientific Features and Classification of Areas identified on the Map

1. Classification of areas in terms of scientific features

- The application of criteria by the Geological Disposal Technology Working Group for identifying features and nationwide classification of areas is illustrated in the figure below. As shown in this figure, areas “assumed to be favorable,” with a relatively high probability that favorable features for geological disposal could be confirmed, are classified as candidates for future site-specific investigations.
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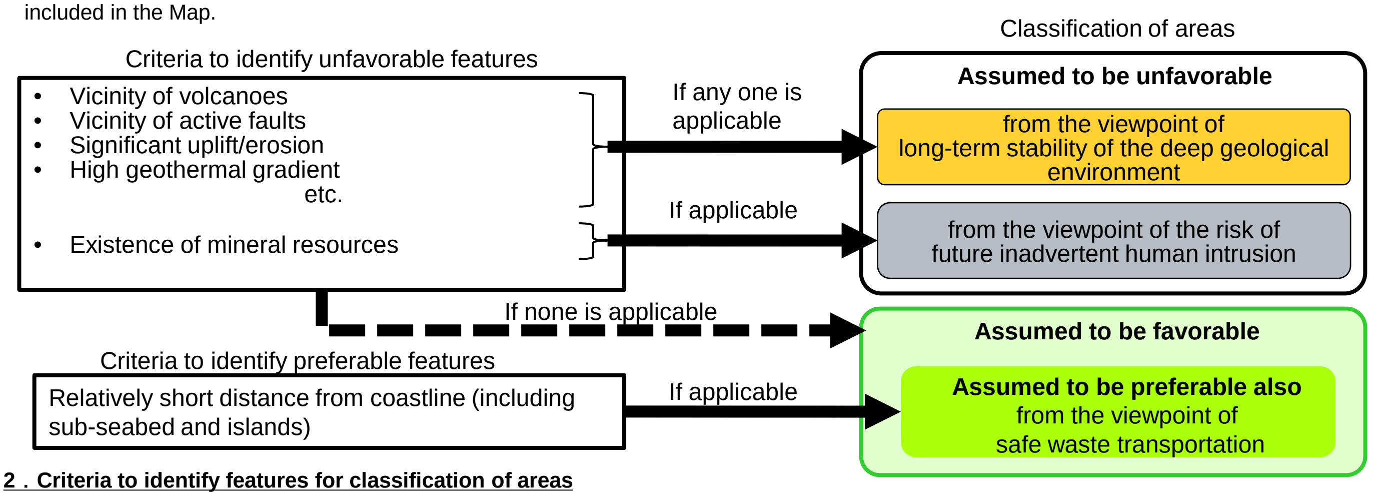

2. Criteria to identify features for classification of areas

- Criteria to identify unfavorable features

Relevant events and processes	Consequence or impact required to be precluded	Criteria	Attachment
Volcanic/igneous activity	Magma intrusion affecting physical isolation	**Vicinity of volcanoes:** Within an area of 15 km from the center of individual Quaternary volcanoes (or the caldera rim if this is greater)	1
Fault activity	Fault activity affecting containment	**Vicinity of active faults:** Within the crush zone around an active fault, the width of which is about 1/100 of the fault length	2
Uplift/erosion	Uplift/erosion affecting physical isolation	**Significant uplift/erosion:** Net erosion greater than 300 m/100,000 years; in coastal areas, accounting for sea-level change, uplift rate greater than 90 m/100,000 years	3
Geothermal activity	Geothermal activity affecting containment	**High geothermal gradient:** Geothermal gradient greater than about 15 °C/100 m	4
Volcanic hydrothermal fluids and deep-seated fluids	Intrusion of exotic groundwater affecting containment	**Presence of hydrothermal water or other deep-seated groundwater:** Groundwater with pH less than 4.8	5
Unconsolidated sediments	Geotechnical instability affecting safe construction	**Location in unconsolidated sediments:** Sediments younger than Middle Pleistocene as cover to a depth of greater than 300 m	6
Pyroclastic flows, etc.	Pyroclastic flows, etc. affecting safe operation	**Susceptibility to distant impacts from pyroclastic flows, etc.:** Traces of Holocene pyroclastic deposits, volcanic rocks and volcanic debris	7
Mineral resources	Future inadvertent human intrusion	**Existence of mineral resources:** Known oil, gas and coal fields, and metallic minerals	8, 9,10

- Criteria to identify preferable features

Relevant events and processes	Requirements for preferring	Criteria	Attachment
Transportation	Safe waste transportation in terms of radiation exposure and nuclear security	**Relatively short distance from coastline** (including sub-seabed and islands): Within about 20 km from coastline	11

○ Process of mapping

- Presence of features is investigated for individual areas based on these criteria. The areas are colored based on applicability in the following order:
  1. Unfavorable features relevant to long-term stability of the deep geological environment (orange)
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  3. Preferable features for safe transportation (green, coastal areas)
- Remaining areas where such features are not present are colored light green. Areas colored green and light green are classified as “assumed to be favorable.”

Q&A on requirements/criteria

Q1	Why are areas within a radius of 15 km from the center of Quaternary volcanoes unfavorable?
A	Over the long term after disposal, it is necessary to avoid magma intrusion into an underground repository. Since past research shows that areas of new volcanic activity occur within a radius of 15 km from the center of existing volcanoes, these areas are set as unfavorable.

Q2	Is it always safe further than 15 km from the center of volcanoes?
A	Although areas of volcanic activity need to be assessed for each volcano, criteria are set based on the finding that these are within 15 km from the center of most volcanoes. Therefore, even outside of 15 km from the center of volcanoes, the risk associated with magma intrusion is not zero. It is thus important to conduct detailed disposal site selection surveys in each area.

Q3	Why are areas within a specific width (fault length × 0.01) of a major active fault (fault length: 10 km or more) unfavorable?
A	Over the long term after disposal, it is necessary to avoid direct impacts of fault displacements on waste packages. In addition, since fault displacement may cause an associated greater flow of groundwater and migration of radionuclides, such effects need to be avoided. Since past research shows that the greater flow of groundwater is expected within areas of about 1/100 of an active fault length, these areas are set as unfavorable.

Q4	Even in the “green” area, is it possible that unknown active faults in addition to those shown in the Nationwide Map of “Scientific Features” relevant for Geological Disposal will be found in the future?
A	That is correct. The “Active fault database of Japan” used for creating the Nationwide Map of “Scientific Features” relevant for Geological Disposal is a comprehensive list of active faults over a certain size, that have been confirmed so far, and all active faults included therein are shown on the Map. The number of the active faults is about 600. However, in addition to these faults, there is a possibility that there are active faults that have not yet been identified for reasons such as not being exposed at the ground surface. The possible existence of such active faults and their effects will be investigated and evaluated in detail during site investigation.

Q5	Why are coastal areas with past uplift of more than 300 m in 100,000 years unfavorable?
A	Over the long term after disposal, it is necessary to avoid a repository approaching the ground surface due to significant uplift and erosion. In coastal areas, in addition to uplift, sea-level lowering may cause erosion of up to 150 m, so in coastal areas with a large amount of uplift in the past, a repository constructed at more than 300 m deep may approach the ground surface in the future. Therefore, these areas are set as unfavorable.

Q6	Why are areas of geothermal gradient greater than 15 °C/100 m categorized as unfavorable?
A	Over the long term after disposal, it is necessary to avoid degradation of the radionuclide containment function due to temperature rise of the buffer material (greatly exceeding 100 °C). With the assumption that the disposal depth is 300 m, considering the subsurface temperature and the thermal output of the waste at that depth, the temperature of the buffer material exceeds 100 °C when the geothermal gradient is greater than 15 °C/100 m. Therefore, these areas are set as unfavorable.

Q&A on requirements/criteria

Q7	Why are areas with groundwater pH less than 4.8 categorized as unfavorable?
A	Over a long period of time after disposal, it is necessary to avoid degradation of the radionuclide containment function of the engineered barriers due to acidic groundwater. Therefore, areas where groundwater pH is less than 4.8, regarded as being effectively acidic, and also areas where the concentration of carbonate is 0.5 mol/dm^3 or more are set as unfavorable.

Q8	Why are areas where geological formations formed less than about 780,000 years ago are distributed to more than 300 m deep categorized as unfavorable?
A	It is necessary to avoid collapse of disposal tunnels during construction and operation. Since past research shows that recent geological formations, formed less than about 780,000 years ago, are mechanically weak, assuming that the disposal depth is 300 m, areas where such geological formations extend to that depth are set as unfavorable.

Q9	Why are areas where pyroclastic flows since about 10,000 years ago are found categorized as unfavorable?
A	During construction and operation, it is necessary to avoid disturbance of surface facilities by volcanic activities. Among the regulatory criteria for nuclear power facilities, with reference to those affecting surface facilities, areas where pyroclastic flows have occurred relatively recently are set as unfavorable.

Q10	Why are areas where coal, oil, natural gas and metallic minerals exist categorized as unfavorable?
A	Over the long term after disposal, it is necessary to avoid human intrusion by exploitation of mineral resources. Since areas where economically valuable coal, oil, natural gas, etc. exist have high probability of exploitation in the future, these areas are set as unfavorable.

Q11	Why are areas within 20 km from the coastline categorized as favorable?
A	Taking into consideration the topographical constraints of Japan (difficulty of long-distance transportation on land) and technical limitations (difficulty of high-speed transportation) based on the properties of the waste (e.g. weights), longer transportation distances on land would increase the risks assumed for public exposure and nuclear security. For this reason, considering the speed and time of required transportation, 20 km is set as the criterion.

For further details of requirements/criteria, please refer to the attachments.

<Attachment 1>

Volcanic/igneous activity (affecting areas of magma)

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

Physical isolation functions should not be impacted by magma intrusion into a repository and/or volcanic eruptions.

◆Criteria to identify unfavorable features

Within 15 km from the center of Quaternary volcanoes.
Within calderas with extent of Quaternary volcanic activity greater than 15 km from the volcanic center.

2. Background

- Magma intrusion and volcanic eruption may cause widespread loss of physical isolation functions of the geological disposal system.
- In Japan, except for the Sea of Japan side of southwest Japan, as the mechanism of volcanic generation, by the water from the oceanic plate subducting beneath the continental plate, part of the upper mantle melts and rises and thus magma (Note 1) is formed. Magma formed in this process may accumulate in magma chambers within the crust (Note 2) and then erupt at the ground surface, forming an island arc of volcanoes.
- Quaternary volcanoes (formed from about 2.6 million years ago to the present day) comprise 111 active volcanoes defined as "erupted within the past 10,000 years and with active fumarole activities" (Coordinating Committee for Prediction of Volcanic Eruption) (as of July 1, 2017).
- Volcanoes are known to have a lifecycle from birth to death, with the thermal lifetime of magma chambers considered to be in the order of hundreds of thousands of years. Volcanoes that have been active for longer periods of time, over several hundreds of thousands of years with gaps of inactivity, possibly result from different heat sources for each active period.

(Note 1) Magma is molten rock, usually generated by high temperatures at the upper part of the mantle. Since it is less dense than surrounding rock, it may rise and penetrate the crust, eventually erupting at the surface.
(Note 2) Crust comprises the solid rock near the surface of the earth. Its thickness is not uniform, being greater in continental areas (about several tens of km) and thinner in oceanic areas (about 5 to 10 km).

3. Rationale for setting criteria

- Based on the distribution of the centers of Quaternary volcanoes and individual volcanic vents (e.g. lateral volcanoes) (Note 3), 97.7% of volcanoes have such vents within a 15 km radius from the volcanic center. Nevertheless, while many volcanoes have individual vents within a few kilometers, there are few that produce distant vents.
- Based on this finding, although risks associated with magma intrusion and volcanic eruption are different for each volcano, as a probabilistic approach, areas within 15 km from the center of Quaternary volcanoes and calderas with Quaternary volcanic activity beyond 15 km from the center are excluded.
- Since volcanic calderas are likely to be subjected to various disturbances at depths of several kilometers underground due to past eruption activities, calderas for which the radius exceeds 15 km are considered also unfavorable.

(Note 3) Quaternary volcanoes are generally composed of individual volcanic vents, such as lateral volcanoes, reflecting the main conduit and several branched conduits.

4. Other points to note

- The focus is on the stability of the underground environment for a long period of time, extending to tens of thousands of years or more.
- Since it is not clear that there is no risk of magma intrusion and volcanic eruption even outside of a radius of 15 km from the center of volcanoes, it is necessary to carefully investigate underground conditions, including possible magma chambers, during the disposal site selection survey.
- Volcanoes are classed as polygenetic volcanoes (stratovolcanoes, shield volcanoes and caldera volcanoes) formed by repeatedly discharging volcanic products from a central crater and monogenetic volcanoes formed only by one eruption event. Monogenetic volcanoes often form a group by aggregation of several volcanoes.
- Since polygenetic volcanoes grow by repeatedly discharging volcanic products from a central crater, generally this becomes the highest point, and it is reasonable to assume the highest elevation as the volcanic center. This is common in volcanoes recently active in Japan. However, for a monogenetic volcano group, since each volcano has a different magma pathway, it is not possible to assume the center of the whole volcanic group from one crater. The elevation of the eruption location is different for each volcano, so the highest point in the group can not be regarded as the volcanic center of the group. Furthermore, for older volcanoes, since land forms change due to erosion, etc., the position of the main crater is likely to be unknown or topographically low. It is thus necessary to identify unfavorable areas for these volcanoes at the time of the disposal site selection survey.
- It is necessary to consider the possible occurrence of new volcanoes in the future in areas with no existing volcanism. Therefore, even in areas without Quaternary volcanoes, as a result of evaluation based on field surveys, it is necessary to avoid areas where there is a possibility of volcanic/igneous activity in the future. Even in areas without temperature/pressure conditions at which magma forms and migrates, in order to investigate the possibility of such conditions arising in the future, it is desirable to establish a new evaluation model of relevant processes.

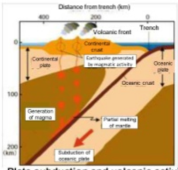
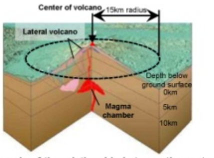


Plate subduction and volcanic activity
(modified from the Headquarters for Earthquake Research Promotion)



Example of the relationship between the center of a volcano and lateral volcanoes, etc. (in the case of polygenetic volcano)
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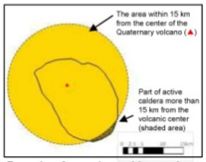

Example of mapping calderas where the area of Quaternary volcanic activity exceeds 15 km (for the case of Kikai)

○ Process of mapping

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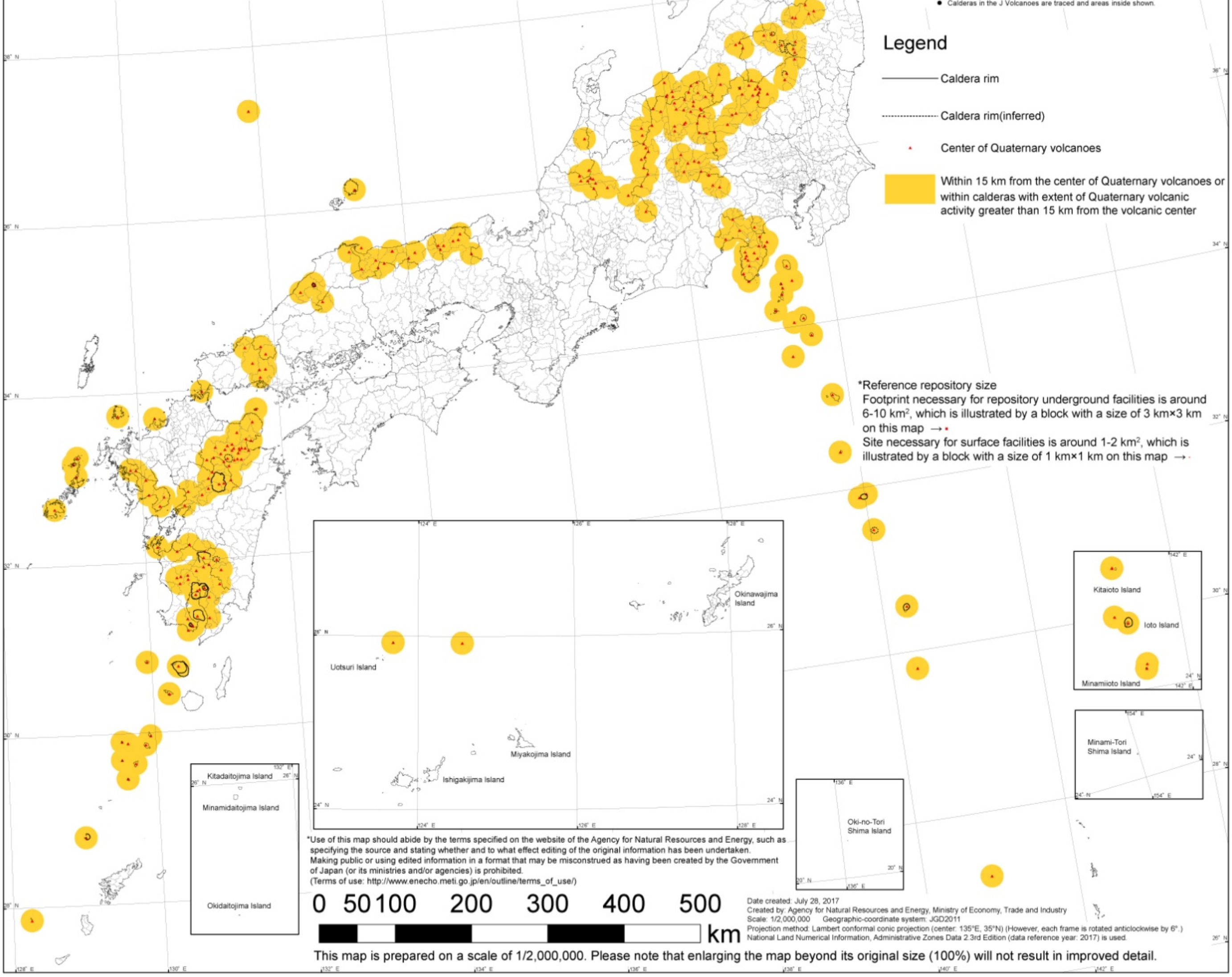
- Catalog of Quaternary Volcanoes in Japan (Committee for the Catalog of Quaternary Volcanoes in Japan, 1999) (hereafter referred to as "the Catalog")

2. Procedures

- Among volcanoes shown in the J Volcanoes, for volcanoes with positions of volcanic centers shown in the Catalog (189 volcanoes), these positions are used.
- Among volcanoes shown in the J Volcanoes, for volcanoes with positions of volcanic centers not shown in the Catalog (267 volcanoes), the following methods are applied:
  - (1) For volcanoes corresponding to volcano types noted as Com (composite volcano or compound volcano), Cal (caldera) or LD (lava dome) in the J Volcanoes (209 volcanoes), the highest elevation points are used as the center of volcanoes.
  - (2) For other volcanoes (not Com, Cal or LD as the volcano type: 58 volcanoes), the centers of volcanic rock distribution (east-west and north-south) are located by drawing and used as the volcanic center (note that volcanoes older than 2 million years (15 volcanoes) would be considered at the time of the disposal site selection survey).
- Areas within a radius of 15 km around the position of the center of volcanoes are shown (except submarine volcanoes whose areas do not overlap land).
- Calderas in the J Volcanoes are traced and areas inside shown.



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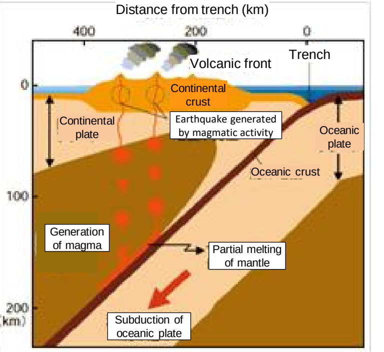

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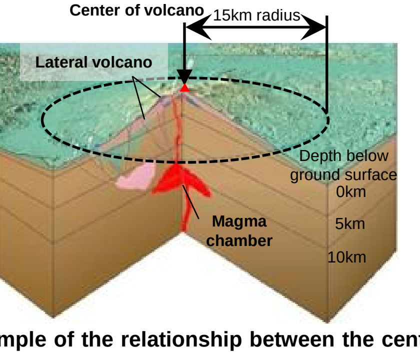

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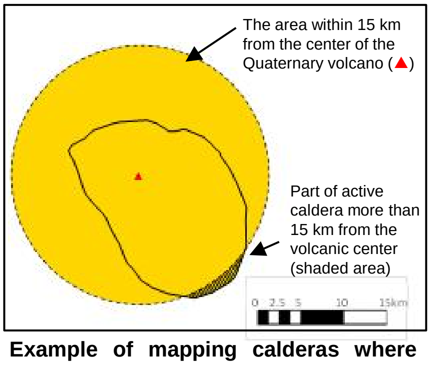

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4. Other points to note

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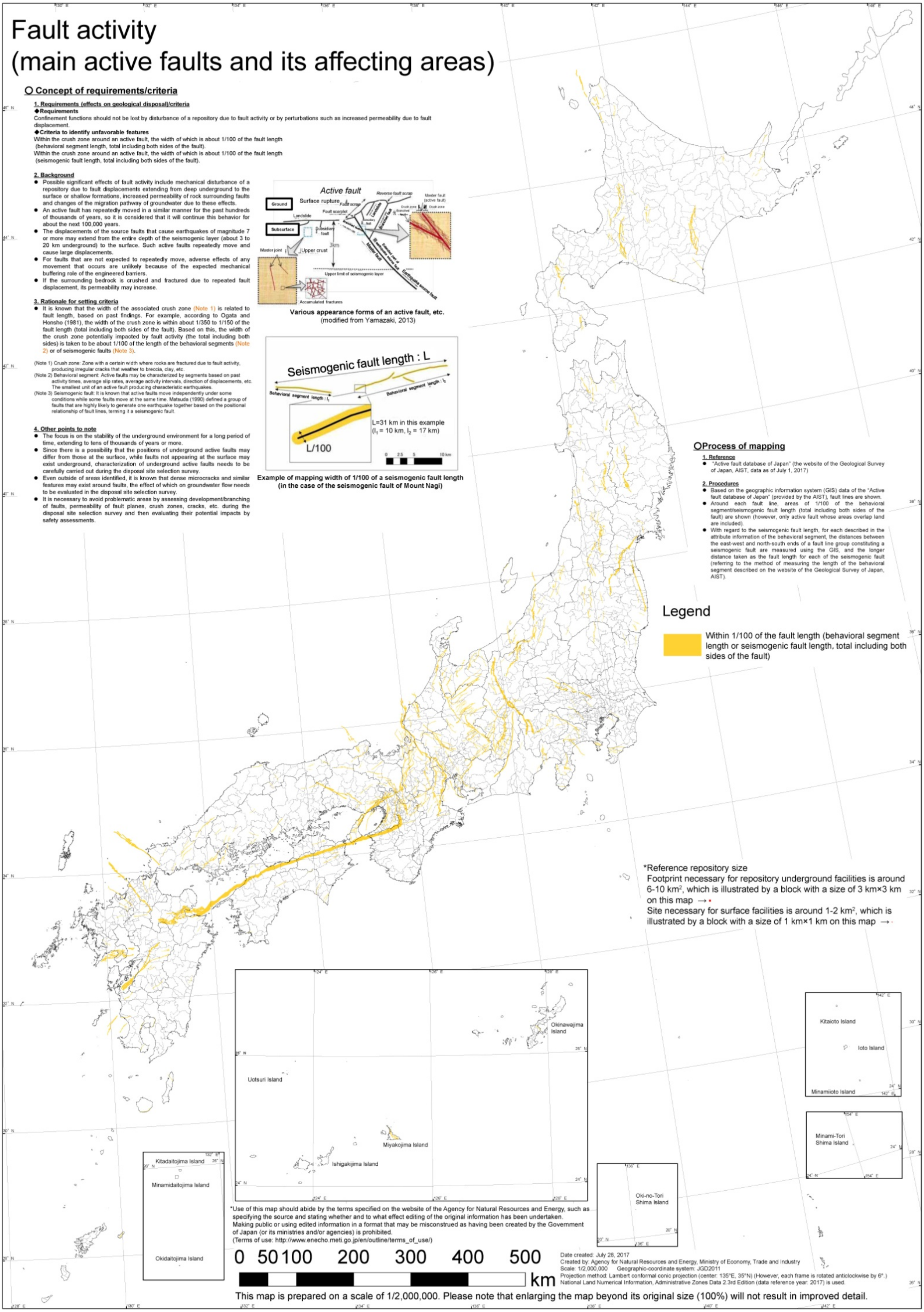
- Among volcanoes shown in the J Volcanoes, for volcanoes with positions of volcanic centers not shown in the Catalog (267 volcanoes), the following methods are applied:
  (1) For volcanoes corresponding to volcano types noted as Com (composite volcano or compound volcano), Cal (caldera) or LD (lava dome) in the J Volcanoes (209 volcanoes), the highest elevation points are used as the center of volcanoes.
  (2) For other volcanoes (not Com, Cal or LD as the volcano type: 58 volcanoes), the centers of volcanic rock distribution (east-west and north-south) are located by drawing and used as the volcanic center (note that volcanoes older than 2 million years (15 volcanoes) would be considered at the time of the disposal site selection survey).
- Areas within a radius of 15 km around the position of the center of volcanoes are shown (except submarine volcanoes whose areas do not overlap land).
- Calderas in the J Volcanoes are traced and areas inside shown.

Fault activity
(main active faults and its affecting areas)



O Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

Confinement functions should not be lost by disturbance of a repository due to fault activity or by perturbations such as increased permeability due to fault displacement.

◆Criteria to identify unfavorable features

Within the crush zone around an active fault, the width of which is about 1/100 of the fault length (behavioral segment length, total including both sides of the fault).

Within the crush zone around an active fault, the width of which is about 1/100 of the fault length (seismogenic fault length, total including both sides of the fault).

2. Background

- Possible significant effects of fault activity include mechanical disturbance of a repository due to fault displacements extending from deep underground to the surface or shallow formations, increased permeability of rock surrounding faults and changes of the migration pathway of groundwater due to these effects.
- An active fault has repeatedly moved in a similar manner for the past hundreds of thousands of years, so it is considered that it will continue this behavior for about the next 100,000 years.
- The displacements of the source faults that cause earthquakes of magnitude 7 or more may extend from the entire depth of the seismogenic layer (about 3 to 20 km underground) to the surface. Such active faults repeatedly move and cause large displacements.
- For faults that are not expected to repeatedly move, adverse effects of any movement that occurs are unlikely because of the expected mechanical buffering role of the engineered barriers.
- If the surrounding bedrock is crushed and fractured due to repeated fault displacement, its permeability may increase.

Various appearance forms of an active fault, etc.
(modified from Yamazaki, 2013)

3. Rationale for setting criteria

- It is known that the width of the associated crush zone (Note 1) is related to fault length, based on past findings. For example, according to Ogata and Honsho (1981), the width of the crush zone is within about 1/350 to 1/150 of the fault length (total including both sides of the fault). Based on this, the width of the crush zone potentially impacted by fault activity (the total including both sides) is taken to be about 1/100 of the length of the behavioral segments (Note 2) or of seismogenic faults (Note 3).

(Note 1) Crush zone: Zone with a certain width where rocks are fractured due to fault activity, producing irregular cracks that weather to breccia, clay, etc.

(Note 2) Behavioral segment: Active faults may be characterized by segments based on past activity times, average slip rates, average activity intervals, direction of displacements, etc. The smallest unit of an active fault producing characteristic earthquakes.

(Note 3) Seismogenic fault: It is known that active faults move independently under some conditions while some faults move at the same time. Matsuda (1990) defined a group of faults that are highly likely to generate one earthquake together based on the positional relationship of fault lines, terming it a seismogenic fault.

Example of mapping width of 1/100 of a seismogenic fault length
(in the case of the seismogenic fault of Mount Nagi)

4. Other points to note

- The focus is on the stability of the underground environment for a long period of time, extending to tens of thousands of years or more.
- Since there is a possibility that the positions of underground active faults may differ from those at the surface, while faults not appearing at the surface may exist underground, characterization of underground active faults needs to be carefully carried out during the disposal site selection survey.
- Even outside of areas identified, it is known that dense microcracks and similar features may exist around faults, the effect of which on groundwater flow needs to be evaluated in the disposal site selection survey.
- It is necessary to avoid problematic areas by assessing development/branching of faults, permeability of fault planes, crush zones, cracks, etc. during the disposal site selection survey and then evaluating their potential impacts by safety assessments.

OProcess of mapping

1. Reference

- "Active fault database of Japan" (the website of the Geological Survey of Japan, AIST, data as of July 1, 2017)

2. Procedures

- Based on the geographic information system (GIS) data of the "Active fault database of Japan" (provided by the AIST), fault lines are shown.
- Around each fault line, areas of 1/100 of the behavioral segment/seismogenic fault length (total including both sides of the fault) are shown (however, only active fault whose areas overlap land are included).
- With regard to the seismogenic fault length, for each described in the attribute information of the behavioral segment, the distances between the east-west and north-south ends of a fault line group constituting a seismogenic fault are measured using the GIS, and the longer distance taken as the fault length for each of the seismogenic fault (referring to the method of measuring the length of the behavioral segment described on the website of the Geological Survey of Japan, AIST).

Legend

Within 1/100 of the fault length (behavioral segment length or seismogenic fault length, total including both sides of the fault)

*Reference repository size
Footprint necessary for repository underground facilities is around 6-10 km², which is illustrated by a block with a size of 3 km×3 km on this map →
Site necessary for surface facilities is around 1-2 km², which is illustrated by a block with a size of 1 km×1 km on this map →

0 50 100 200 300 400 500 km

Date created: July 28, 2017
Created by: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry
Scale: 1/2,000,000 Geographic-coordinate system: JGD2011
Projection method: Lambert conformal conic projection (center: 135°E, 35°N) (However, each frame is rotated anticlockwise by 6°.)
National Land Numerical Information, Administrative Zones Data 2.3rd Edition (data reference year: 2017) is used.

This map is prepared on a scale of 1/2,000,000. Please note that enlarging the map beyond its original size (100%) will not result in improved detail.

Fault activity (main active faults and its affecting areas)

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

Confinement functions should not be lost by disturbance of a repository due to fault activity or by perturbations such as increased permeability due to fault displacement.

◆Criteria to identify unfavorable features

Within the crush zone around an active fault, the width of which is about 1/100 of the fault length (behavioral segment length, total including both sides of the fault).

Within the crush zone around an active fault, the width of which is about 1/100 of the fault length (seismogenic fault length, total including both sides of the fault).

2. Background

- Possible significant effects of fault activity include mechanical disturbance of a repository due to fault displacements extending from deep underground to the surface or shallow formations, increased permeability of rock surrounding faults and changes of the migration pathway of groundwater due to these effects.
- An active fault has repeatedly moved in a similar manner for the past hundreds of thousands of years, so it is considered that it will continue this behavior for about the next 100,000 years.
- The displacements of the source faults that cause earthquakes of magnitude 7 or more may extend from the entire depth of the seismogenic layer (about 3 to 20 km underground) to the surface. Such active faults repeatedly move and cause large displacements.
- For faults that are not expected to repeatedly move, adverse effects of any movement that occurs are unlikely because of the expected mechanical buffering role of the engineered barriers.
- If the surrounding bedrock is crushed and fractured due to repeated fault displacement, its permeability may increase.

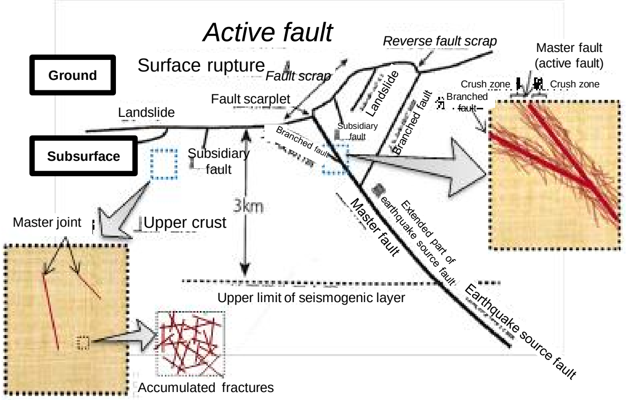
3. Rationale for setting criteria

- It is known that the width of the associated crush zone (Note 1) is related to fault length, based on past findings. For example, according to Ogata and Honsho (1981), the width of the crush zone is within about 1/350 to 1/150 of the fault length (total including both sides of the fault). Based on this, the width of the crush zone potentially impacted by fault activity (the total including both sides) is taken to be about 1/100 of the length of the behavioral segments (Note 2) or of seismogenic faults (Note 3).

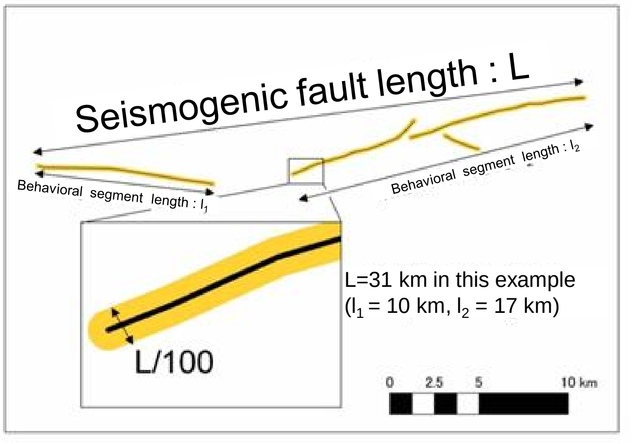
(Note 1) Crush zone: Zone with a certain width where rocks are fractured due to fault activity, producing irregular cracks that weather to breccia, clay, etc.

(Note 2) Behavioral segment: Active faults may be characterized by segments based on past activity times, average slip rates, average activity intervals, direction of displacements, etc. The smallest unit of an active fault producing characteristic earthquakes.

(Note 3) Seismogenic fault: It is known that active faults move independently under some conditions while some faults move at the same time. Matsuda (1990) defined a group of faults that are highly likely to generate one earthquake together based on the positional relationship of fault lines, terming it a seismogenic fault.



Various appearance forms of an active fault, etc.
(modified from Yamazaki, 2013)



Example of mapping width of 1/100 of a seismogenic fault length (in the case of the seismogenic fault of Mount Nagi)

4. Other points to note

- The focus is on the stability of the underground environment for a long period of time, extending to tens of thousands of years or more.
- Since there is a possibility that the positions of underground active faults may differ from those at the surface, while faults not appearing at the surface may exist underground, characterization of underground active faults needs to be carefully carried out during the disposal site selection survey.
- Even outside of areas identified, it is known that dense microcracks and similar features may exist around faults, the effect of which on groundwater flow needs to be evaluated in the disposal site selection survey.
- It is necessary to avoid problematic areas by assessing development/branching of faults, permeability of fault planes, crush zones, cracks, etc. during the disposal site selection survey and then evaluating their potential impacts by safety assessments.

○Process of mapping

1. Reference

- "Active fault database of Japan" (the website of the Geological Survey of Japan, AIST, data as of July 1, 2017)

2. Procedures

- Based on the geographic information system (GIS) data of the "Active fault database of Japan" (provided by the AIST), fault lines are shown.
- Around each fault line, areas of 1/100 of the behavioral segment/seismogenic fault length (total including both sides of the fault) are shown (however, only active fault whose areas overlap land are included).
- With regard to the seismogenic fault length, for each described in the attribute information of the behavioral segment, the distances between the east-west and north-south ends of a fault line group constituting a seismogenic fault are measured using the GIS, and the longer distance taken as the fault length for each of the seismogenic fault (referring to the method of measuring the length of the behavioral segment described on the website of the Geological Survey of Japan, AIST).

Uplift/erosion
(significantly affecting areas of uplift/erosion)

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

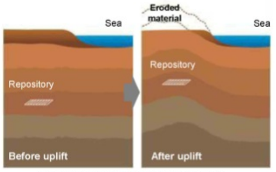
The physical isolation functions of a repository should not be significantly impacted by uplift and erosion.

◆Criteria to identify unfavorable features

In the nationwide database, areas where it is considered highly likely that erosion due to uplift and sea level lowering will exceed 300 m in 100,000 years (specifically, for coastal areas where a maximum erosion of 150 m is expected, areas with a maximum uplift rate of 90 m or more/100,000 years).

2. Background

- If repository depth is significantly reduced due to uplift and erosion, the physical isolation function of the geological disposal system could be lost.
- Uplift occurs mainly due to crustal changes associated with plate movement.
- For inland areas, potential approaches for quantifying the amount of erosion include assuming that the amount of uplift equals that of erosion and, when there are high uncertainties in the prediction of the amount of uplift, assuming conservatively that erosion progresses down to a base-level (e.g. the riverbed surface where large rivers join together).
- For coastal areas, potential approaches for quantifying the amount of erosion include assuming sea-level changes cause erosion and deriving temporal changes in the amount of erosion from the relative height of the geomorphic surface and sea-level (the base-level of erosion). When high uncertainties remain, conservatively evaluation of the amount of erosion can be made by assuming sea level drops by up to 150 m in glacial periods. Information on the depth of the alluvium base may also serve as a basis for estimating the amount of future erosion.



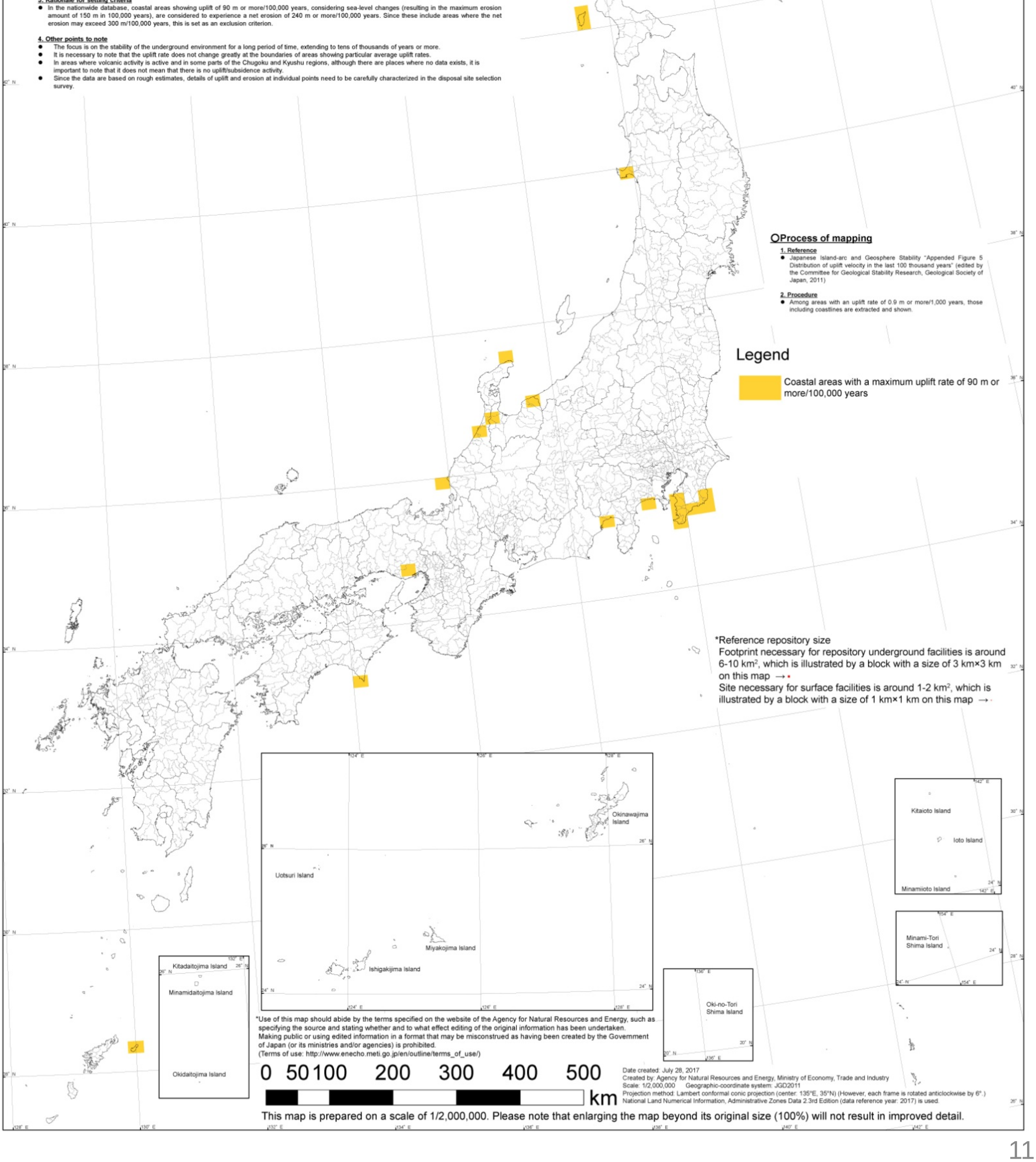
Schematic illustration of uplift/erosion

3. Rationale for setting criteria

- In the nationwide database, coastal areas showing uplift of 90 m or more/100,000 years, considering sea-level changes (resulting in the maximum erosion amount of 150 m in 100,000 years), are considered to experience a net erosion of 240 m or more/100,000 years. Since these include areas where the net erosion may exceed 300 m/100,000 years, this is set as an exclusion criterion.

4. Other points to note

- The focus is on the stability of the underground environment for a long period of time, extending to tens of thousands of years or more.
- It is necessary to note that the uplift rate does not change greatly at the boundaries of areas showing particular average uplift rates.
- In areas where volcanic activity is active and in some parts of the Chugoku and Kyushu regions, although there are places where no data exists, it is important to note that it does not mean that there is no uplift/subsidence activity.
- Since the data are based on rough estimates, details of uplift and erosion at individual points need to be carefully characterized in the disposal site selection survey.



○Process of mapping

1. Reference

- Japanese Island-arc and Geosphere Stability "Appended Figure 5 Distribution of uplift velocity in the last 100 thousand years" (edited by the Committee for Geological Stability Research, Geological Society of Japan, 2011)

2. Procedure

- Among areas with an uplift rate of 0.9 m or more/1,000 years, those including coastlines are extracted and shown.

Legend

Coastal areas with a maximum uplift rate of 90 m or more/100,000 years

*Reference repository size

Footprint necessary for repository underground facilities is around 6-10 km², which is illustrated by a block with a size of 3 km×3 km on this map →

Site necessary for surface facilities is around 1-2 km², which is illustrated by a block with a size of 1 km×1 km on this map →

*Use of this map should abide by the terms specified on the website of the Agency for Natural Resources and Energy, such as specifying the source and stating whether and to what effect editing of the original information has been undertaken.
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(Terms of use: http://www.enecho.meti.go.jp/en/outline/terms_of_use/)

Date created: July 28, 2017
Created by: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry
Scale: 1/2,000,000 Geographic-coordinate system: JGD2011
Projection method: Lambert conformal conic projection (center: 135°E, 35°N) (However, each frame is rotated anticlockwise by 6°.)
National Land Numerical Information, Administrative Zones Data 2.3rd Edition (data reference year: 2017) is used.

This map is prepared on a scale of 1/2,000,000. Please note that enlarging the map beyond its original size (100%) will not result in improved detail.

Uplift/erosion (significantly affecting areas of uplift/erosion)

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

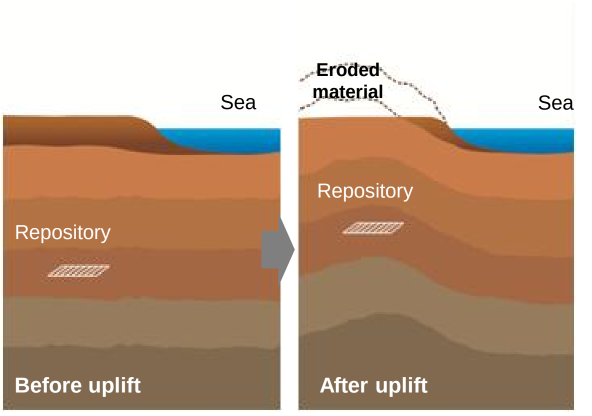
The physical isolation functions of a repository should not be significantly impacted by uplift and erosion.

◆Criteria to identify unfavorable features

In the nationwide database, areas where it is considered highly likely that erosion due to uplift and sea level lowering will exceed 300 m in 100,000 years (specifically, for coastal areas where a maximum erosion of 150 m is expected, areas with a maximum uplift rate of 90 m or more/100,000 years).

2. Background

- If repository depth is significantly reduced due to uplift and erosion, the physical isolation function of the geological disposal system could be lost.
- Uplift occurs mainly due to crustal changes associated with plate movement.
- For inland areas, potential approaches for quantifying the amount of erosion include assuming that the amount of uplift equals that of erosion and, when there are high uncertainties in the prediction of the amount of uplift, assuming conservatively that erosion progresses down to a base-level (e.g. the riverbed surface where large rivers join together).
- For coastal areas, potential approaches for quantifying the amount of erosion include assuming sea-level changes cause erosion and deriving temporal changes in the amount of erosion from the relative height of the geomorphic surface and sea-level (the base-level of erosion). When high uncertainties remain, conservatively evaluation of the amount of erosion can be made by assuming sea level drops by up to 150 m in glacial periods. Information on the depth of the alluvium base may also serve as a basis for estimating the amount of future erosion.



Schematic illustration of uplift/erosion

3. Rationale for setting criteria

- In the nationwide database, coastal areas showing uplift of 90 m or more/100,000 years, considering sea-level changes (resulting in the maximum erosion amount of 150 m in 100,000 years), are considered to experience a net erosion of 240 m or more/100,000 years. Since these include areas where the net erosion may exceed 300 m/100,000 years, this is set as an exclusion criterion.

4. Other points to note

- The focus is on the stability of the underground environment for a long period of time, extending to tens of thousands of years or more.
- It is necessary to note that the uplift rate does not change greatly at the boundaries of areas showing particular average uplift rates.
- In areas where volcanic activity is active and in some parts of the Chugoku and Kyushu regions, although there are places where no data exists, it is important to note that it does not mean that there is no uplift/subsidence activity.
- Since the data are based on rough estimates, details of uplift and erosion at individual points need to be carefully characterized in the disposal site selection survey.

○Process of mapping

1. Reference

- Japanese Island-arc and Geosphere Stability “Appended Figure 5 Distribution of uplift velocity in the last 100 thousand years” (edited by the Committee for Geological Stability Research, Geological Society of Japan, 2011)

2. Procedure

- Among areas with an uplift rate of 0.9 m or more/1,000 years, those including coastlines are extracted and shown.

<Attachment 4>

Geothermal activity (significantly affecting areas of subsurface temperature)

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

The confinement functions of the disposal system should not be significantly impacted by geothermal activity.

◆Criteria to identify unfavorable features

Areas where geothermal gradients cannot allow assurance that the buffer material remains below 100 °C at the disposal depth.
(Areas with geothermal gradients greater than about 15 °C/100 m, referring to the "H12: Project to Establish the Scientific and Technical Basis for HLW Disposal in Japan, Second Progress Report on Research and Development for the Geological Disposal of HLW in Japan").

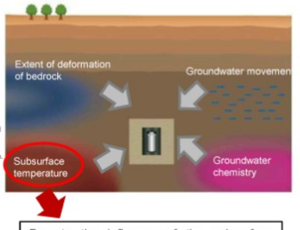
2. Background

- At a temperature of 90 °C, thermal alternation of buffer material is minimal and no functional deterioration occurs. However if the temperature exceeds 130 °C, alteration of montmorillonite could reach approx. 50% during a period of 100,000 years or more and at 170 °C, such alternation could occur within about 10,000 years.
- The temperature of the buffer material varies depending on design aspects, such as the decay heat of the waste, the thermal properties of the engineered barriers, the disposal depth and the footprint of the waste packages, in addition to site characteristics, which are the ambient rock temperature and thermal properties of the bedrock.

3. Rationale for setting criteria

- Assuming a footprint of the waste packages based on the size of the underground facilities (approx. 6-10 km^2) assumed at present, considering the warming effect of surrounding waste packages in that case, the allowable rock temperature will be 60 °C for the temperature of the buffer material to reach 100 °C. If an average surface temperature of 15 °C is assumed for the minimum allowed depth of 300 m, the maximum geothermal gradient will be about 15 °C/100 m (Note 1), which is set as the exclusion criterion.

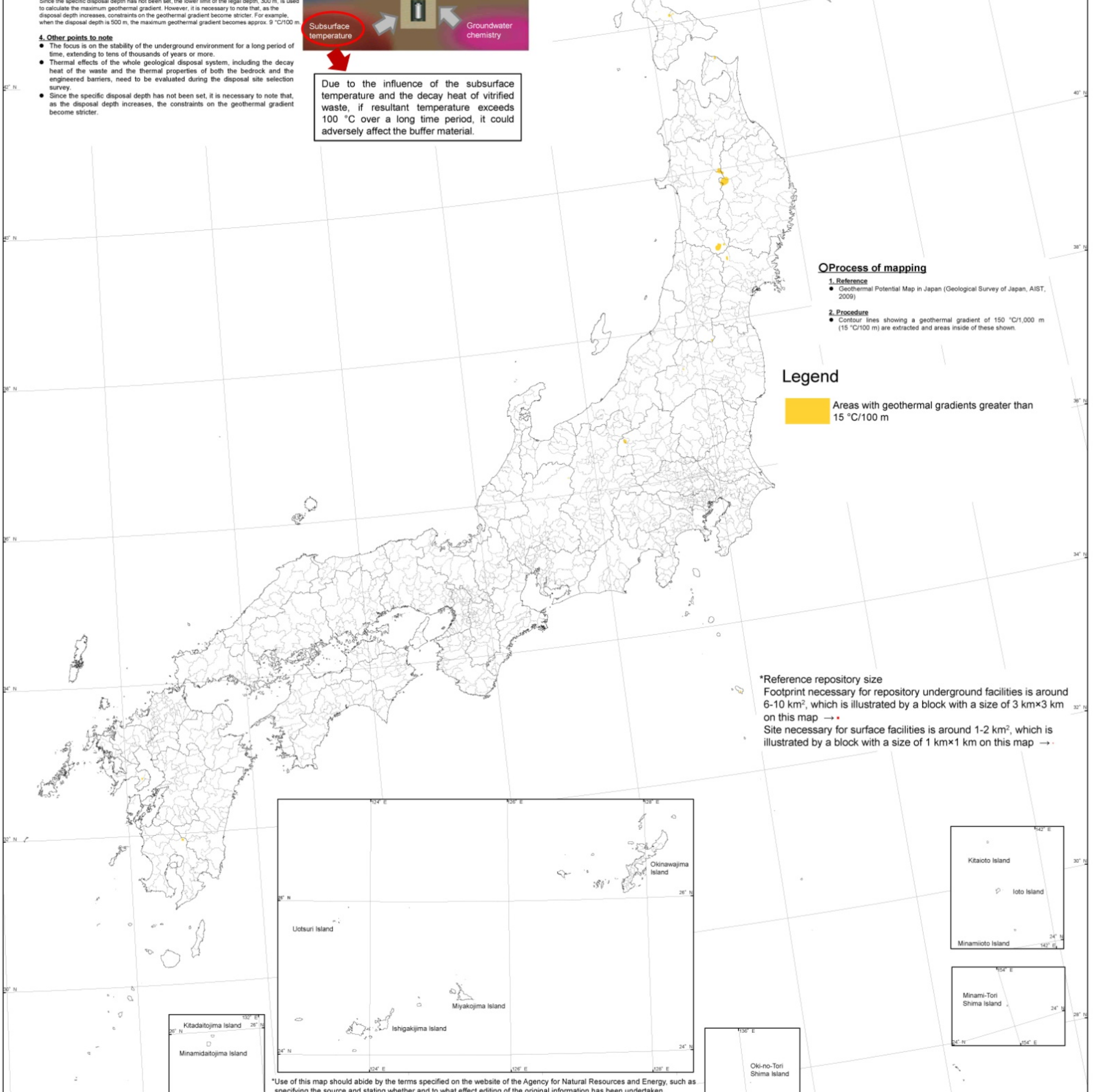
(Note 1) Geothermal gradient: The rate of increase of rock temperature as a function of depth.
[Approx. 60 °C (allowable temperature) - 15 °C (surface temperature)] ÷ [300 m (emplacement depth)/100 m] = approx. 15 °C/100 m
Since the specific disposal depth has not been set, the lower limit of the legal depth, 300 m, is used to calculate the maximum geothermal gradient. However, it is necessary to note that, as the disposal depth increases, constraints on the geothermal gradient become stricter. For example, when the disposal depth is 500 m, the maximum geothermal gradient becomes approx. 9 °C/100 m.



Due to the influence of the subsurface temperature and the decay heat of vitrified waste, if resultant temperature exceeds 100 °C over a long time period, it could adversely affect the buffer material.

4. Other points to note

- The focus is on the stability of the underground environment for a long period of time, extending to tens of thousands of years or more.
- Thermal effects of the whole geological disposal system, including the decay heat of the waste and the thermal properties of both the bedrock and the engineered barriers, need to be evaluated during the disposal site selection survey.
- Since the specific disposal depth has not been set, it is necessary to note that, as the disposal depth increases, the constraints on the geothermal gradient become stricter.



○Process of mapping

1. Reference

- Geothermal Potential Map in Japan (Geological Survey of Japan, AIST, 2009)

2. Procedure

- Contour lines showing a geothermal gradient of 150 °C/1,000 m (15 °C/100 m) are extracted and areas inside of these shown.

Legend

Areas with geothermal gradients greater than 15 °C/100 m

*Reference repository size
Footprint necessary for repository underground facilities is around 6-10 km^2, which is illustrated by a block with a size of 3 km×3 km on this map →
Site necessary for surface facilities is around 1-2 km^2, which is illustrated by a block with a size of 1 km×1 km on this map →

*Use of this map should abide by the terms specified on the website of the Agency for Natural Resources and Energy, such as specifying the source and stating whether and to what effect editing of the original information has been undertaken.
Making public or using edited information in a format that may be misconstrued as having been created by the Government of Japan (or its ministries and/or agencies) is prohibited.
(Terms of use: http://www.enecho.meti.go.jp/en/outline/terms_of_use/)

0 50 100 200 300 400 500 km

Date created: July 28, 2017
Created by: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry
Scale: 1/2,000,000 Geographic-coordinate system: JGD2011
Projection method: Lambert conformal conic projection (center: 135°E, 35°N) (However, each frame is rotated anticlockwise by 6°.)
National Land Numerical Information, Administrative Zones Data 2.3rd Edition (data reference year: 2017) is used.

This map is prepared on a scale of 1/2,000,000. Please note that enlarging the map beyond its original size (100%) will not result in improved detail.

Geothermal activity (significantly affecting areas of subsurface temperature)

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

The confinement functions of the disposal system should not be significantly impacted by geothermal activity.

◆Criteria to identify unfavorable features

Areas where geothermal gradients cannot allow assurance that the buffer material remains below 100 °C at the disposal depth.

(Areas with geothermal gradients greater than about 15 °C/100 m, referring to the "H12: Project to Establish the Scientific and Technical Basis for HLW Disposal in Japan, Second Progress Report on Research and Development for the Geological Disposal of HLW in Japan").

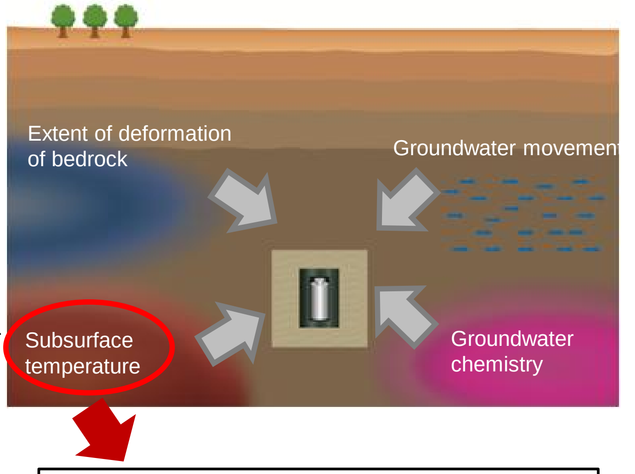
2. Background

- At a temperature of 90 °C, thermal alternation of buffer material is minimal and no functional deterioration occurs. However if the temperature exceeds 130 °C, alteration of montmorillonite could reach approx. 50% during a period of 100,000 years or more and at 170 °C, such alternation could occur within about 10,000 years.
- The temperature of the buffer material varies depending on design aspects, such as the decay heat of the waste, the thermal properties of the engineered barriers, the disposal depth and the footprint of the waste packages, in addition to site characteristics, which are the ambient rock temperature and thermal properties of the bedrock.

3. Rationale for setting criteria

- Assuming a footprint of the waste packages based on the size of the underground facilities (approx. 6-10 km^2) assumed at present, considering the warming effect of surrounding waste packages in that case, the allowable rock temperature will be 60 °C for the temperature of the buffer material to reach 100 °C. If an average surface temperature of 15 °C is assumed for the minimum allowed depth of 300 m, the maximum geothermal gradient will be about 15 °C/100 m (Note 1), which is set as the exclusion criterion.

(Note 1) Geothermal gradient: The rate of increase of rock temperature as a function of depth.
[Approx. 60 °C (allowable temperature) - 15 °C (surface temperature)] ÷ [300 m (emplacement depth)/100 m] = approx. 15 °C/100 m
Since the specific disposal depth has not been set, the lower limit of the legal depth, 300 m, is used to calculate the maximum geothermal gradient. However, it is necessary to note that, as the disposal depth increases, constraints on the geothermal gradient become stricter. For example, when the disposal depth is 500 m, the maximum geothermal gradient becomes approx. 9 °C/100 m.



Due to the influence of the subsurface temperature and the decay heat of vitrified waste, if resultant temperature exceeds 100 °C over a long time period, it could adversely affect the buffer material.

4. Other points to note

- The focus is on the stability of the underground environment for a long period of time, extending to tens of thousands of years or more.
- Thermal effects of the whole geological disposal system, including the decay heat of the waste and the thermal properties of both the bedrock and the engineered barriers, need to be evaluated during the disposal site selection survey.
- Since the specific disposal depth has not been set, it is necessary to note that, as the disposal depth increases, the constraints on the geothermal gradient become stricter.

○Process of mapping

1. Reference

- Geothermal Potential Map in Japan (Geological Survey of Japan, AIST, 2009)

2. Procedure

- Contour lines showing a geothermal gradient of 150 °C/1,000 m (15 °C/100 m) are extracted and areas inside of these shown.

<Attachment 5>

Volcanic hydrothermal fluids and deep-seated fluids

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆**Requirements**

The confinement function of the disposal system should not be significantly impacted due to the inflow of volcanic hydrothermal fluids or deep-seated fluids with unfavorable chemistry.

◆**Criteria to identify unfavorable features**

Areas with groundwater with a pH of less than 4.8 or inorganic carbon species concentration of 0.5 mol/dm^3 (mol/L) or more (Note 1).

(Note 1) Inorganic carbon species: Carbonic acid (H_2CO_3 or CO_2(aq)), bicarbonate ion (HCO_3^-) and carbonate ion (CO_3^{2-})

2. Background

- Groundwater with very low or high pH may increase the dissolution rate of vitrified waste; increase permeability and decrease sorption capacity due to alteration of buffer material; increase the solubility of radionuclides; and decrease sorption capacity of the natural barrier. Also, high concentrations of chemical species such as carbonate ions may lead to passivation of the overpack and hence localized corrosion. Causes of such unusual groundwater conditions are known as follows:
- Although mechanisms of formation and migration of deep-seated fluids are still being studied and many aspects are still unclear, fluids with low pH and high concentrations of carbonate species resulting from subducting slabs or the mantle may migrate into overlying formations.
- The reaction of ultrabasic rocks and groundwater may result in high pH values. However, the pH of such groundwater is at most about 11, and at this level, the chemical function of the buffer material would avoid significant impacts on the corrosion resistance of the overpack or the solubility of most radionuclides. In addition, since the alteration of bentonite (buffer material) is minor and its effect is limited in extent, it is considered that the movement and inflow of the high pH groundwater reacting with the ultrabasic rocks would not have a significant effect on confinement functions.

Groundwater with low-pH or high concentrations of chemical species such as carbonate ions can adversely affect:
· Dissolution of the vitrified waste
· Corrosion of the overpack
· The sorption capacity of the natural barrier

3. Rationale for setting criteria

- Low pH is taken to be less than pH 4.8, which is effectively acidic, while concentrations of carbonate of 0.5 mol/dm^3 or more are required for the passivation and localized corrosion of the carbon steel overpack; therefore these are used as exclusion criteria.

4. Other points to note

- The focus is on the stability of the underground environment for a long period of time, extending to tens of thousands of years or more.
- Since data on groundwater pH and concentrations of carbonate in the "Geothermal Potential Map in Japan" (Geological Survey of Japan, AIST, 2009) are point (coordinate) data, it is difficult to express them by areas. Thus it is necessary to identify unfavorable areas at the time of the disposal site selection survey.
- In fact, it is assumed that volcanic hydrothermal fluids and deep-seated fluids spread over potential areas depending on underground structures such as cracks. Therefore, it is necessary to investigate them at individual locations.

○Process of mapping

1. Reference

- Geothermal Potential Map in Japan (Geological Survey of Japan, AIST, 2009)

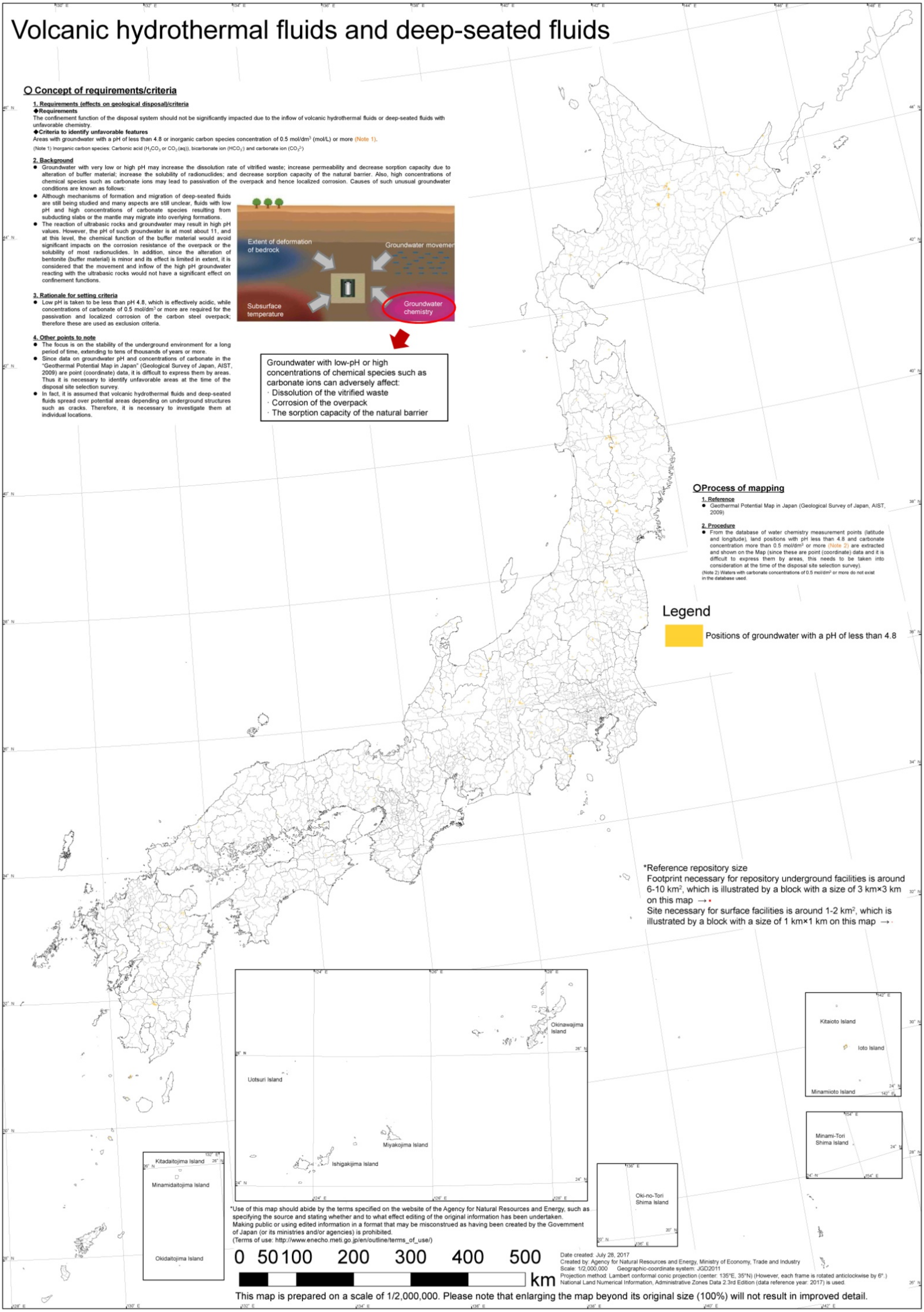
2. Procedure

- From the database of water chemistry measurement points (latitude and longitude), land positions with pH less than 4.8 and carbonate concentration more than 0.5 mol/dm^3 or more (Note 2) are extracted and shown on the Map (since these are point (coordinate) data and it is difficult to express them by areas, this needs to be taken into consideration at the time of the disposal site selection survey).

(Note 2) Waters with carbonate concentrations of 0.5 mol/dm^3 or more do not exist in the database used.

Legend

Positions of groundwater with a pH of less than 4.8



*Reference repository size

Footprint necessary for repository underground facilities is around 6-10 km^2, which is illustrated by a block with a size of 3 km×3 km on this map →

Site necessary for surface facilities is around 1-2 km^2, which is illustrated by a block with a size of 1 km×1 km on this map →

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0 50 100 200 300 400 500 km

Date created: July 28, 2017
Created by: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry
Scale: 1/2,000,000 Geographic-coordinate system: JGD2011
Projection method: Lambert conformal conic projection (center: 135°E, 35°N) (However, each frame is rotated anticlockwise by 6°.)
National Land Numerical Information, Administrative Zones Data 2.3rd Edition (data reference year: 2017) is used.

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<Attachment 5: Explanatory text in figure>

Volcanic hydrothermal fluids and deep-seated fluids

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

The confinement function of the disposal system should not be significantly impacted due to the inflow of volcanic hydrothermal fluids or deep-seated fluids with unfavorable chemistry.

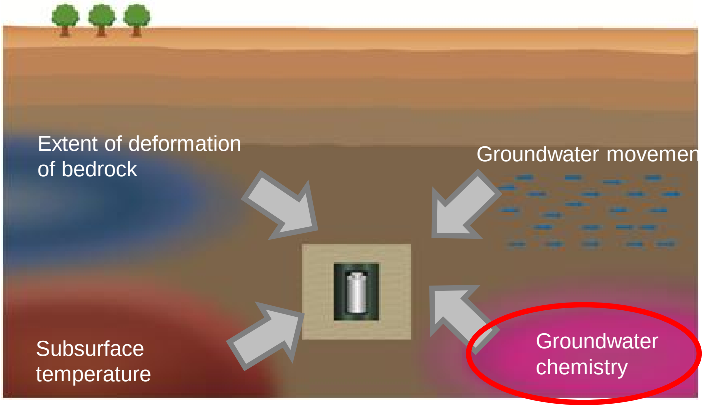
◆Criteria to identify unfavorable features

Areas with groundwater with a pH of less than 4.8 or inorganic carbon species concentration of 0.5 mol/dm^3 (mol/L) or more (Note 1).

(Note 1) Inorganic carbon species: Carbonic acid (H_2CO_3 or CO_2 (aq)), bicarbonate ion (HCO_3^-) and carbonate ion (CO_3^{2-})

2. Background

- Groundwater with very low or high pH may increase the dissolution rate of vitrified waste; increase permeability and decrease sorption capacity due to alteration of buffer material; increase the solubility of radionuclides; and decrease sorption capacity of the natural barrier. Also, high concentrations of chemical species such as carbonate ions may lead to passivation of the overpack and hence localized corrosion. Causes of such unusual groundwater conditions are known as follows:
- Although mechanisms of formation and migration of deep-seated fluids are still being studied and many aspects are still unclear, fluids with low pH and high concentrations of carbonate species resulting from subducting slabs or the mantle may migrate into overlying formations.
- The reaction of ultrabasic rocks and groundwater may result in high pH values. However, the pH of such groundwater is at most about 11, and at this level, the chemical function of the buffer material would avoid significant impacts on the corrosion resistance of the overpack or the solubility of most radionuclides. In addition, since the alteration of bentonite (buffer material) is minor and its effect is limited in extent, it is considered that the movement and inflow of the high pH groundwater reacting with the ultrabasic rocks would not have a significant effect on confinement functions.



Groundwater with low-pH or high concentrations of chemical species such as carbonate ions can adversely affect:
· Dissolution of the vitrified waste
· Corrosion of the overpack
· The sorption capacity of the natural barrier

3. Rationale for setting criteria

- Low pH is taken to be less than pH 4.8, which is effectively acidic, while concentrations of carbonate of 0.5 mol/dm^3 or more are required for the passivation and localized corrosion of the carbon steel overpack; therefore these are used as exclusion criteria.

4. Other points to note

- The focus is on the stability of the underground environment for a long period of time, extending to tens of thousands of years or more.
- Since data on groundwater pH and concentrations of carbonate in the "Geothermal Potential Map in Japan" (Geological Survey of Japan, AIST, 2009) are point (coordinate) data, it is difficult to express them by areas. Thus it is necessary to identify unfavorable areas at the time of the disposal site selection survey.
- In fact, it is assumed that volcanic hydrothermal fluids and deep-seated fluids spread over potential areas depending on underground structures such as cracks. Therefore, it is necessary to investigate them at individual locations.

○Process of mapping

1. Reference

- Geothermal Potential Map in Japan (Geological Survey of Japan, AIST, 2009)

2. Procedure

- From the database of water chemistry measurement points (latitude and longitude), land positions with pH less than 4.8 and carbonate concentration more than 0.5 mol/dm^3 or more (Note 2) are extracted and shown on the Map (since these are point (coordinate) data and it is difficult to express them by areas, this needs to be taken into consideration at the time of the disposal site selection survey).

(Note 2) Waters with carbonate concentrations of 0.5 mol/dm^3 or more do not exist in the database used.

Unconsolidated sediments

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

Geological formations hosting a repository should not be unconsolidated sediments.

◆Criteria to identify unfavorable features

Areas where geological formations laid down since the Middle Pleistocene (about 780,000 years ago) are distributed at a depth of 300 m or more.

2. Background

- Since the underground facilities for geological disposal are constructed below a depth of 300 m, if unconsolidated sediments exist at such depths, there is a high risk that tunnels will collapse during excavation and safety of workers will be threatened.
- The "Standard Specifications for Tunneling" (Japan Society of Civil Engineers, 2016) defines "unconsolidated host rock" (Note 1) as "unconsolidated or poorly consolidated sandy or gravelly soils, volcanic products consisting of volcanic ash, lapilli, pumice, etc."
- According to Yoda et al. (2009), "since the Middle Pleistocene, there is a clear difference in the physical properties of the host rock, resulting in difficulties in the control of rock displacements such as subsidence."

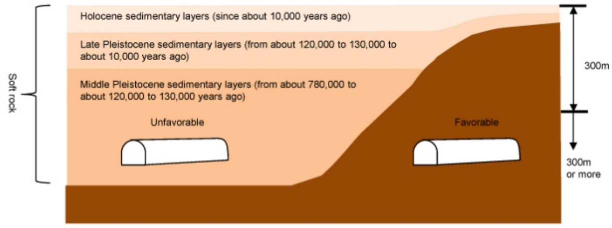
(Note 1) Unconsolidated host rock: Same as unconsolidated sediments

3. Rationale for setting criteria

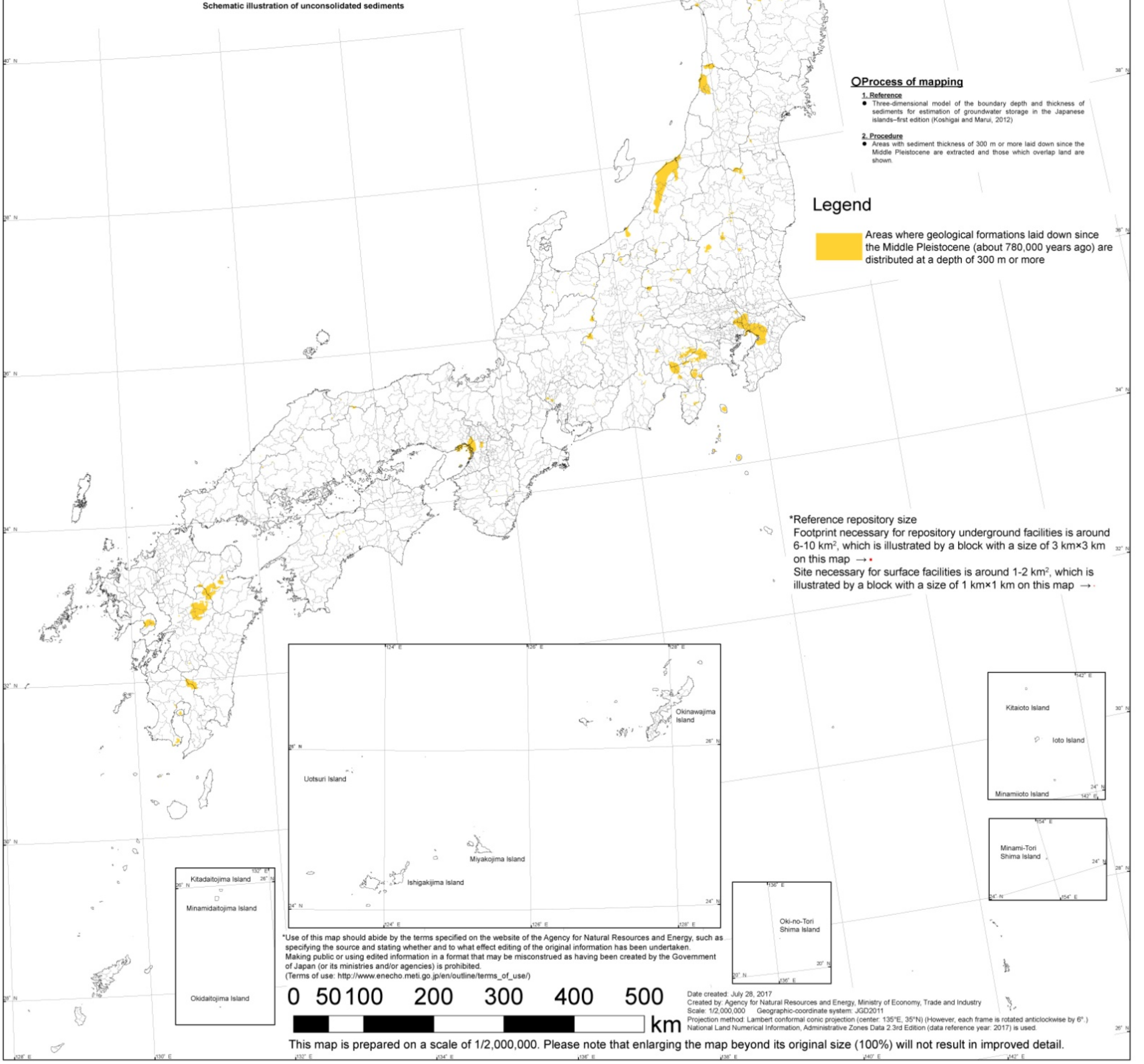
- Since it is considered that geological formations laid down since the Middle Pleistocene (about 780,000 years ago) can be assumed to be unconsolidated, areas where such formations are distributed at a depth of 300 m or more are set as an exclusion criterion.

4. Other points to note

- The focus is on safety during construction and operation, which should be taken into consideration for periods of several decades.
- Since the "Standard Specifications for Tunneling" illustrates many "construction examples in unconsolidated host rock," and since there are many examples of unconsolidated sedimentary layers, where construction is possible by adopting engineering measures, it is necessary to note that capability of specific engineering countermeasures can be determined by conducting a survey of relevant locations.



Schematic illustration of unconsolidated sediments



○Process of mapping

1. Reference

- Three-dimensional model of the boundary depth and thickness of sediments for estimation of groundwater storage in the Japanese islands–first edition (Koshigai and Marui, 2012)

2. Procedure

- Areas with sediment thickness of 300 m or more laid down since the Middle Pleistocene are extracted and those which overlap land are shown.

Legend

Areas where geological formations laid down since the Middle Pleistocene (about 780,000 years ago) are distributed at a depth of 300 m or more

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0 50 100 200 300 400 500 km

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＜Attachment 6: Explanatory text in figure＞

Unconsolidated sediments

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

Geological formations hosting a repository should not be unconsolidated sediments.

◆Criteria to identify unfavorable features

Areas where geological formations laid down since the Middle Pleistocene (about 780,000 years ago) are distributed at a depth of 300 m or more.

2. Background

- Since the underground facilities for geological disposal are constructed below a depth of 300 m, if unconsolidated sediments exist at such depths, there is a high risk that tunnels will collapse during excavation and safety of workers will be threatened.
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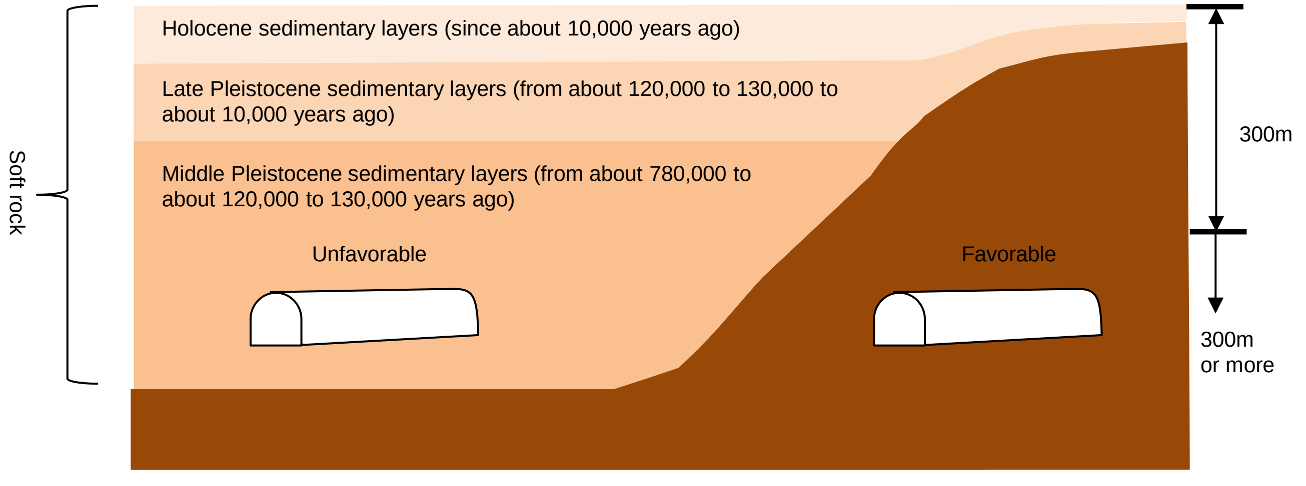
(Note 1) Unconsolidated host rock: Same as unconsolidated sediments

3. Rationale for setting criteria

- Since it is considered that geological formations laid down since the Middle Pleistocene (about 780,000 years ago) can be assumed to be unconsolidated, areas where such formations are distributed at a depth of 300 m or more are set as an exclusion criterion.

4. Other points to note

- The focus is on safety during construction and operation, which should be taken into consideration for periods of several decades.
- Since the “Standard Specifications for Tunneling” illustrates many “construction examples in unconsolidated host rock,” and since there are many examples of unconsolidated sedimentary layers, where construction is possible by adopting engineering measures, it is necessary to note that capability of specific engineering countermeasures can be determined by conducting a survey of relevant locations.



Schematic illustration of unconsolidated sediments

○Process of mapping

1. Reference

- Three-dimensional model of the boundary depth and thickness of sediments for estimation of groundwater storage in the Japanese islands–first edition (Koshigai and Marui, 2012)

2. Procedure

- Areas with sediment thickness of 300 m or more laid down since the Middle Pleistocene are extracted and those which overlap land are shown.

Pyroclastic flows, etc.

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆**Requirements**

The safety of the facilities should not be impaired by the effect of volcanic events such as pyroclastic flows during operation.

◆**Criteria to identify unfavorable features**

Distribution areas of Holocene (since approx. 10,000 years ago) pyroclastic deposits, volcanic rocks and volcanic debris.

2. Background

- The effects of events such as pyroclastic flows during operation may impair the safety of the facilities.
- Pyroclastic flows are events in which high temperature volcanic products discharged by eruptions flow down mountain slopes at high speed. Generally, since flows are driven by gravity, areas impacted are affected by the local land form.
- Pyroclastic flows and similar volcanic events on the ground surface are unlikely to significantly affect underground facilities.

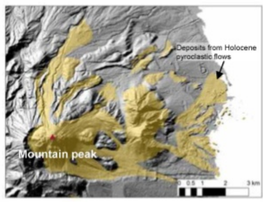
3. Rationale for setting criteria

- The "Guide for Evaluating the Effects of Volcanoes on Nuclear Power Generation Plants" (hereafter referred to as the "Guide for Evaluating the Effects of Volcanoes") defines natural phenomena such as pyroclastic flows as volcanic events that cannot be dealt with design countermeasures and hence should be avoided by siting.
- In the Guide for Evaluating the Effects of Volcanoes, areas with surrounding volcanoes whose future activities cannot be precluded due to Holocene activity (since about 10,000 years ago) and where possible effects of pyroclastic flows, lava flows, debris flows, landslides, slope failures, opening of new craters, and crustal changes are not demonstrably small, are considered unsuitable for siting. Therefore, these are set as criteria.

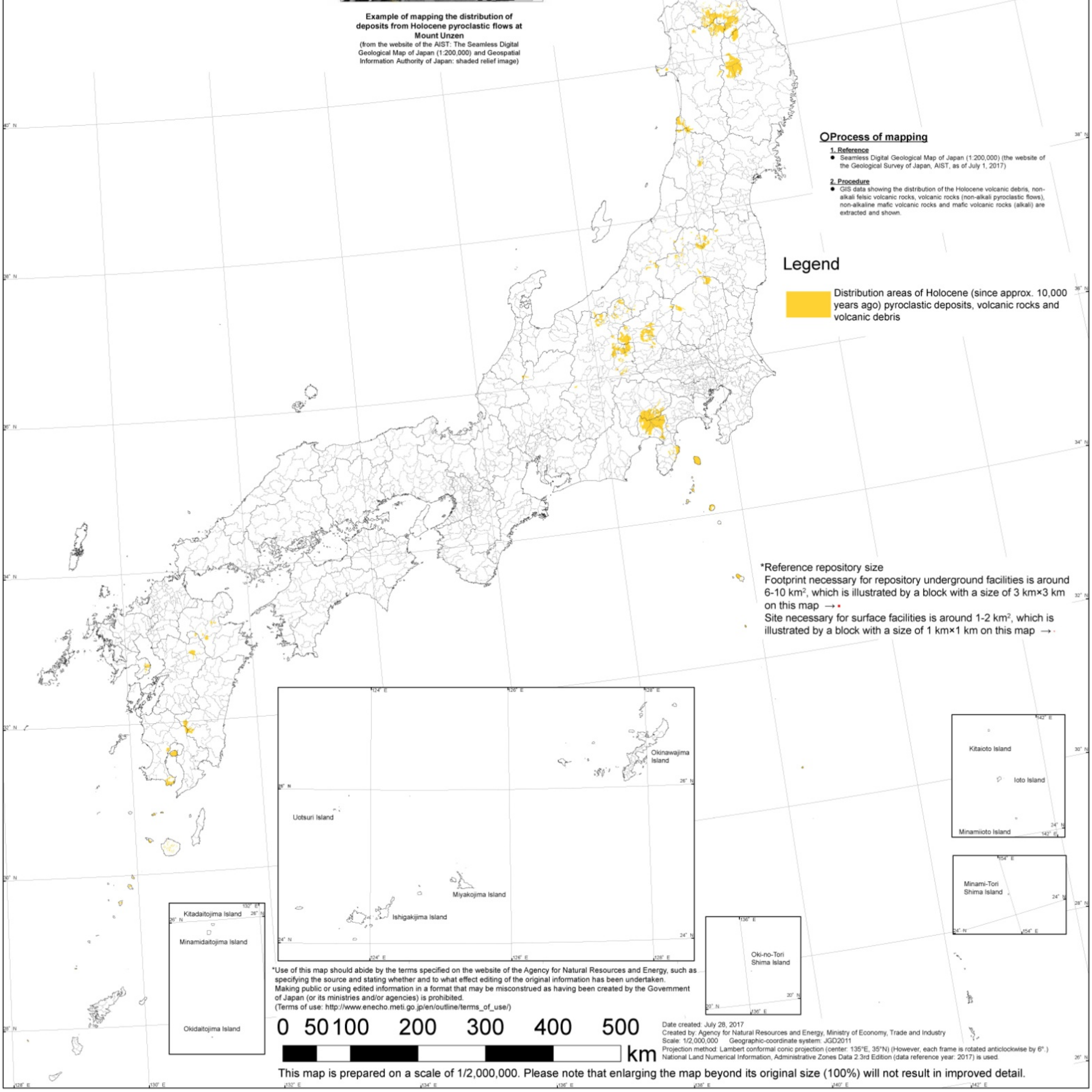
4. Other points to note

- The focus is on safety during construction and operation, which should be taken into consideration for periods of several decades.
- It is important to note that, in the Guide for Evaluating the Effects of Volcanoes, future activities of Quaternary volcanoes (since about 2.6 million years ago) are required to be evaluated, even if there was no activity in the Holocene.

Pyroclastic flow at Mount Unzen (June 24, 1994)
(from the website of the Japan Meteorological Agency)



Example of mapping the distribution of deposits from Holocene pyroclastic flows at Mount Unzen
(from the website of the AIST: The Seamless Digital Geological Map of Japan (1:200,000) and Geospatial Information Authority of Japan: shaded relief image)



○Process of mapping

1. Reference

- Seamless Digital Geological Map of Japan (1:200,000) (the website of the Geological Survey of Japan, AIST, as of July 1, 2017)

2. Procedure

- GIS data showing the distribution of the Holocene volcanic debris, non-alkali felsic volcanic rocks, volcanic rocks (non-alkali pyroclastic flows), non-alkaline mafic volcanic rocks and mafic volcanic rocks (alkali) are extracted and shown.

Legend

Distribution areas of Holocene (since approx. 10,000 years ago) pyroclastic deposits, volcanic rocks and volcanic debris

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0 50 100 200 300 400 500 km

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Pyroclastic flows, etc.

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

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◆Criteria to identify unfavorable features

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○Process of mapping

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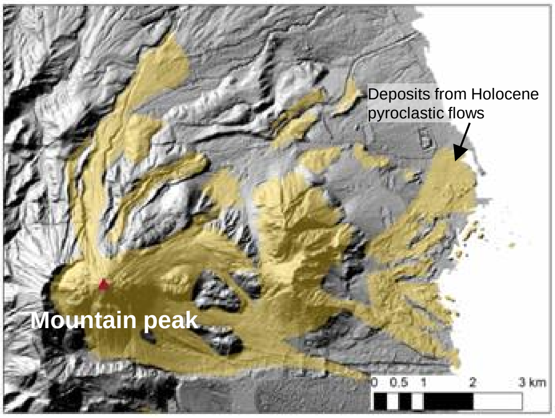

Example of mapping the distribution of deposits from Holocene pyroclastic flows at Mount Unzen
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＜Attachment 8＞

Mineral resources: Oil fields/gas fields

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

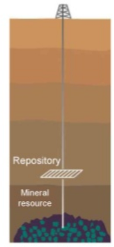
The physical isolation and confinement functions of the geological disposal system should not be perturbed by inadvertent human intrusion due to the existence of currently recognized, economically valuable mineral resources.

◆Criteria to identify unfavorable features

For minerals stipulated by the Mining Law, areas where the existence of technically exploitable mineral resources with large reserves are shown in a database developed on a nationwide scale (however, as these include areas where the existence of minerals has not been confirmed, it is necessary to note that such areas may need to be confirmed by conducting a local survey).

2. Background

- Mineral exploration and exploitation are generally considered as potential causes of future human intrusion. The Final Disposal Act stipulates that preliminary investigation areas need to be selected from those included for the literature survey subject to the condition that there is no record of the existence of economically valuable mineral resources in geological formations in the proposed areas.
- The minerals stipulated by the Mining Law include metallic minerals (e.g. gold and silver), nonmetallic minerals (e.g. gypsum and limestone), and fuel minerals (e.g. coal and oil).
- Although utilization of hot springs or groundwater occurs, groundwater is mostly pumped up from the shallow aquifers in Japan, and there would be few cases that reach the disposal depth of about 300 m or more. Currently, it is difficult to consistently judge the importance of geothermal sources, hot springs and groundwater; so this should be re-considered in the future.
- As Carbon Dioxide Capture and Storage (CCS) can be considered as utilization of underground space, it is necessary to pay close attention to the future development of this topic.
- The definition of "economically valuable mineral resources" may differ with time, depending also on regional characteristics. International consensus is that, while recognizing such uncertainties, resources with current economic value should be avoided as far as possible.
- Examples of nationwide databases for oil, natural gas, coal and metallic minerals are the "Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition)," the "Coal Fields of Japan (2nd ed.)" and the "Collection of location data about the deposit in Japan, 2nd Ed."



Representation of human intrusion associated with resource exploration

3. Rationale for setting criteria

- The "Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition)" was compiled from a comprehensive knowledge base collected up to the year of issue, identifying areas where oil and natural gas can be exploited and shows areas where production occurs (or past production occurred). It also identifies areas where geological formations with the possibility of producing oil and gas are found (e.g. areas where thick Neogene sediments are distributed). With a focus on "those with high probability of exploitation in the future," areas where oil and gas production are actually confirmed are shown on the Map.

4. Other points to note

- The focus is on reducing the risk of human intrusion for a long period of time, extending to tens of thousands of years or more.
- Since the "Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition)" is about 40 years old, it is necessary to bear in mind potential changes from the current situation, either because reserves have been reduced due to subsequent exploitation or oil and gas fields discovered since then are not included in the data.
- It is necessary to note that, since nationwide data is used, the existence of mineral resources is not consistently confirmed in the "areas where the existence of technically exploitable mineral resources with large reserves are shown," and there may be points where the absence of minerals can be confirmed by conducting a survey.
- It is necessary to note that, since the original of the "Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition)" comprises analog data, errors may occur in importing data by tracing to utilize them for the Nationwide Map of "Scientific Features" relevant for Geological Disposal.

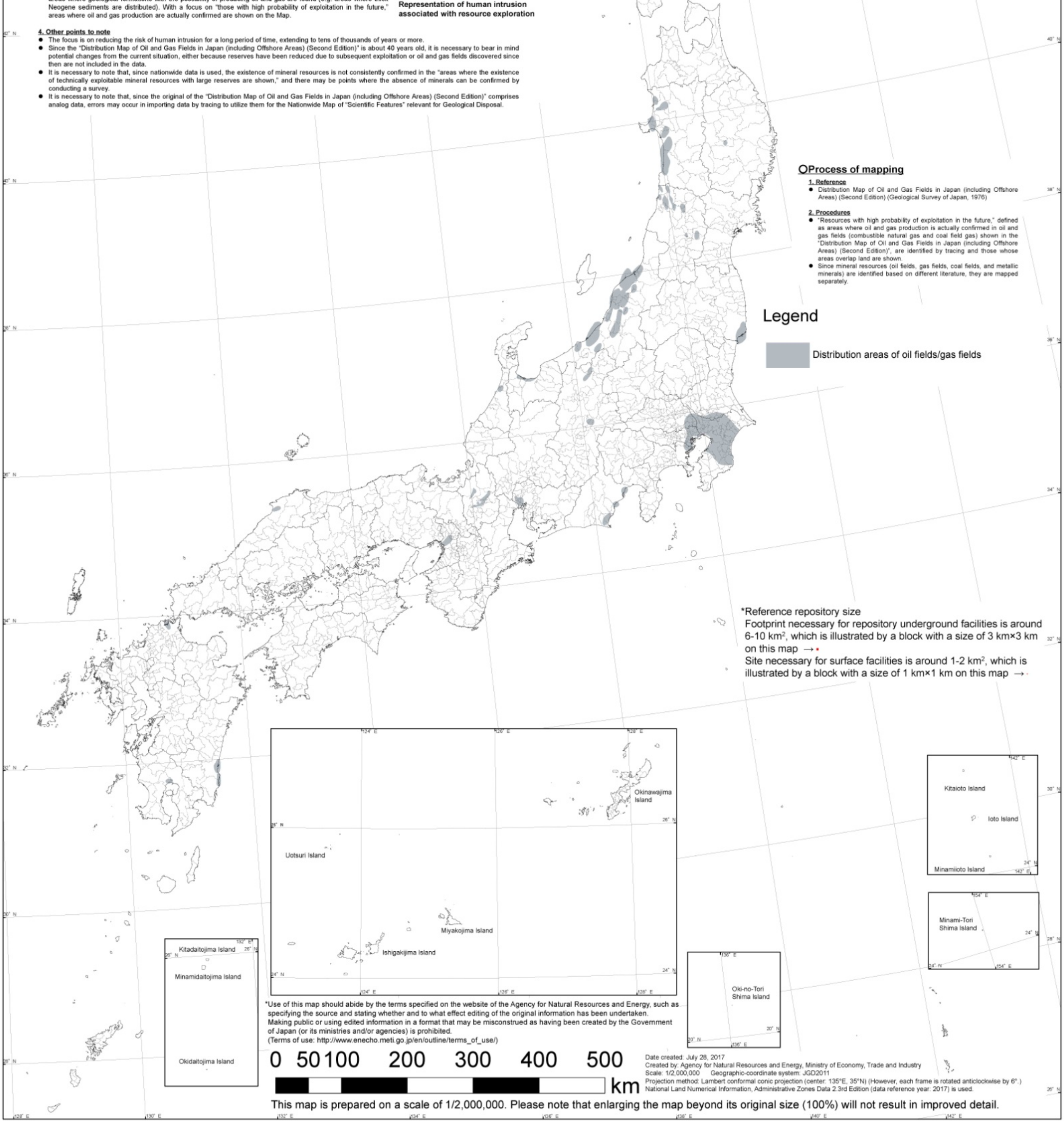
○Process of mapping

1. Reference

- Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition) (Geological Survey of Japan, 1976)

2. Procedures

- "Resources with high probability of exploitation in the future," defined as areas where oil and gas production is actually confirmed in oil and gas fields (combustible natural gas and coal field gas) shown in the "Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition)", are identified by tracing and those whose areas overlap land are shown.
- Since mineral resources (oil fields, gas fields, coal fields, and metallic minerals) are identified based on different literature, they are mapped separately.



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Mineral resources: Oil fields/gas fields

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

The physical isolation and confinement functions of the geological disposal system should not be perturbed by inadvertent human intrusion due to the existence of currently recognized, economically valuable mineral resources.

◆Criteria to identify unfavorable features

For minerals stipulated by the Mining Law, areas where the existence of technically exploitable mineral resources with large reserves are shown in a database developed on a nationwide scale (however, as these include areas where the existence of minerals has not been confirmed, it is necessary to note that such areas may need to be confirmed by conducting a local survey).

2. Background

- Mineral exploration and exploitation are generally considered as potential causes of future human intrusion. The Final Disposal Act stipulates that preliminary investigation areas need to be selected from those included for the literature survey subject to the condition that there is no record of the existence of economically valuable mineral resources in geological formations in the proposed areas.
- The minerals stipulated by the Mining Law include metallic minerals (e.g. gold and silver), nonmetallic minerals (e.g. gypsum and limestone), and fuel minerals (e.g. coal and oil).
- Although utilization of hot springs or groundwater occurs, groundwater is mostly pumped up from the shallow aquifers in Japan, and there would be few cases that reach the disposal depth of about 300 m or more. Currently, it is difficult to consistently judge the importance of geothermal sources, hot springs and groundwater; so this should be re-considered in the future.
- As Carbon Dioxide Capture and Storage (CCS) can be considered as utilization of underground space, it is necessary to pay close attention to the future development of this topic.
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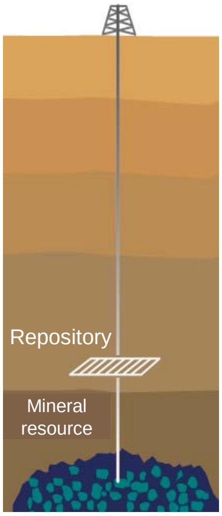
- Examples of nationwide databases for oil, natural gas, coal and metallic minerals are the “Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition),” the “Coal Fields of Japan (2nd ed.)” and the “Collection of location data about the deposit in Japan, 2nd Ed.”



Representation of human intrusion associated with resource exploration

3. Rationale for setting criteria

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4. Other points to note

- The focus is on reducing the risk of human intrusion for a long period of time, extending to tens of thousands of years or more.
- Since the “Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition)” is about 40 years old, it is necessary to bear in mind potential changes from the current situation, either because reserves have been reduced due to subsequent exploitation or oil and gas fields discovered since then are not included in the data.
- It is necessary to note that, since nationwide data is used, the existence of mineral resources is not consistently confirmed in the “areas where the existence of technically exploitable mineral resources with large reserves are shown,” and there may be points where the absence of minerals can be confirmed by conducting a survey.
- It is necessary to note that, since the original of the “Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition)” comprises analog data, errors may occur in importing data by tracing to utilize them for the Nationwide Map of “Scientific Features” relevant for Geological Disposal.

○Process of mapping

1. Reference

- Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition) (Geological Survey of Japan, 1976)

2. Procedures

- “Resources with high probability of exploitation in the future,” defined as areas where oil and gas production is actually confirmed in oil and gas fields (combustible natural gas and coal field gas) shown in the “Distribution Map of Oil and Gas Fields in Japan (including Offshore Areas) (Second Edition)”, are identified by tracing and those whose areas overlap land are shown.
- Since mineral resources (oil fields, gas fields, coal fields, and metallic minerals) are identified based on different literature, they are mapped separately.

Mineral resources: Coal fields

○ Concept of requirements/criteria

1. and 2. as for "mineral resources: oil fields/gas fields."

3. Rationale for setting criteria

- The "Coal fields of Japan (2nd ed.)" compiles areas where coal could be practically exploited, based on a comprehensive knowledge collected up to the year of issue, identifying main exploited coal fields. For the areas shown thereof together with and without an amount of coal reserves, the former are shown on the Map, with a focus on "those with high probability of exploitation in the future."

4. Other points to note

- The focus is on reducing the risk of human intrusion for a long period of time, extending to tens of thousands of years or more.
- Since the "Coal Fields of Japan (2nd ed.)" is about 40 years old, it is necessary to bear in mind potential changes from the current situation, either because reserves have been reduced due to subsequent exploitation or coalfields discovered since then are not included in the data.
- It is necessary to note that, since nationwide data is used, the existence of mineral resources is not consistently confirmed in the "areas where the existence of technically exploitable mineral resources with large reserves are shown," and there may be points where the absence of minerals can be confirmed by conducting a survey.
- In addition, although the "Coal Fields of Japan (2nd ed.)" identifies areas both with and without coal reserves, for those without reserves, it is necessary to confirm this at the time of the disposal site selection survey.
- It is necessary to note that since the original of the "Coal Fields of Japan (2nd ed.)" comprises analog data, errors may occur in importing data by tracing to utilize them for the Nationwide Map of "Scientific Features" relevant for Geological Disposal.

Representation of human intrusion associated with resource exploration

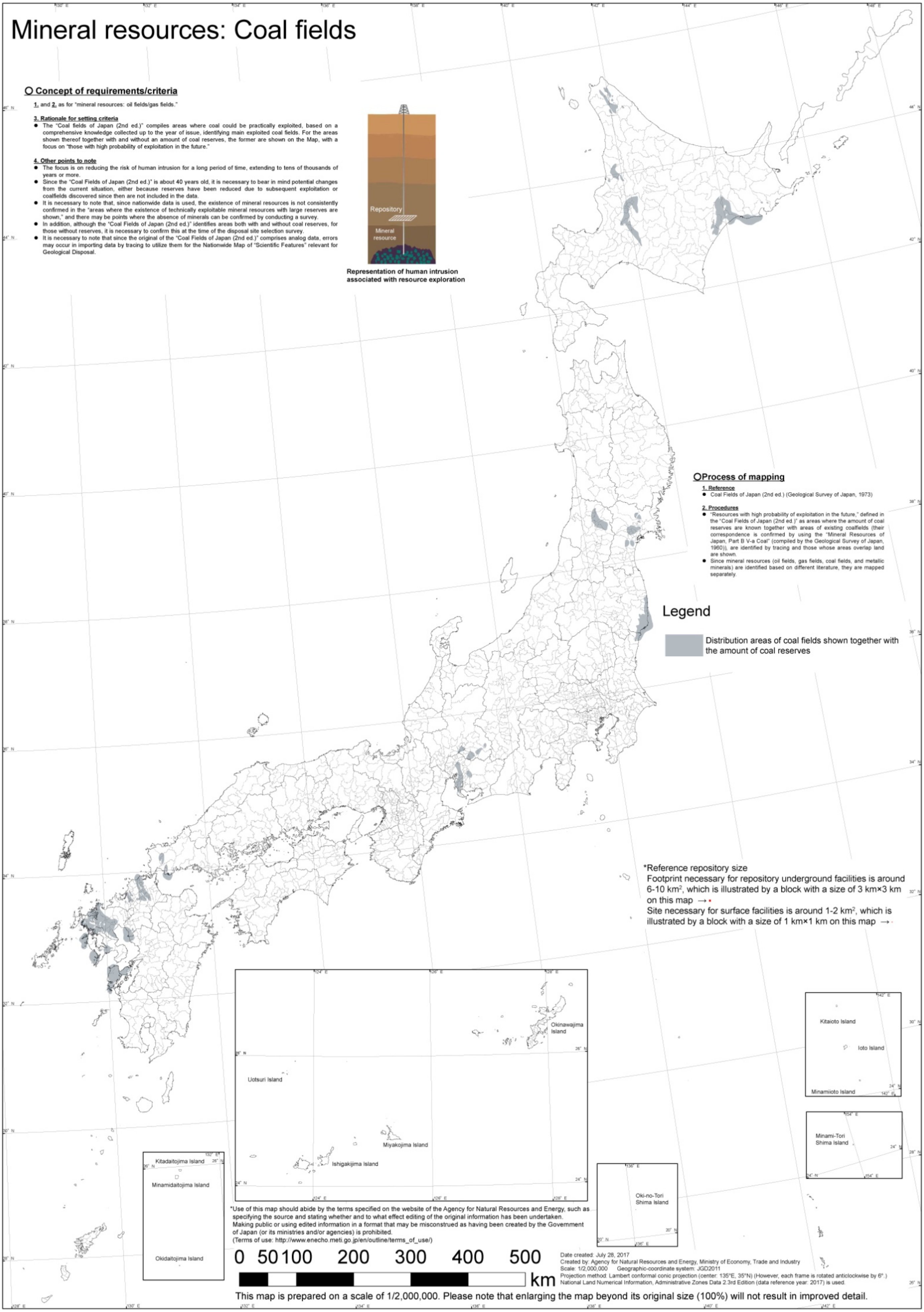
○Process of mapping

1. Reference

- Coal Fields of Japan (2nd ed.) (Geological Survey of Japan, 1973)

2. Procedures

- "Resources with high probability of exploitation in the future," defined in the "Coal Fields of Japan (2nd ed.)" as areas where the amount of coal reserves are known together with areas of existing coalfields (their correspondence is confirmed by using the "Mineral Resources of Japan, Part B V-a Coal" (compiled by the Geological Survey of Japan, 1960)), are identified by tracing and those whose areas overlap land are shown.
- Since mineral resources (oil fields, gas fields, coal fields, and metallic minerals) are identified based on different literature, they are mapped separately.



*Reference repository size
Footprint necessary for repository underground facilities is around 6-10 km², which is illustrated by a block with a size of 3 km×3 km on this map →
Site necessary for surface facilities is around 1-2 km², which is illustrated by a block with a size of 1 km×1 km on this map →

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Date created: July 28, 2017
Created by: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry
Scale: 1/2,000,000 Geographic-coordinate system: JGD2011
Projection method: Lambert conformal conic projection (center: 135°E, 35°N) (However, each frame is rotated anticlockwise by 6°.)
National Land Numerical Information, Administrative Zones Data 2.3rd Edition (data reference year: 2017) is used.

This map is prepared on a scale of 1/2,000,000. Please note that enlarging the map beyond its original size (100%) will not result in improved detail.

Mineral resources: Coal fields

○ Concept of requirements/criteria

1. and **2.** as for “mineral resources: oil fields/gas fields.”

3. Rationale for setting criteria

- The “Coal fields of Japan (2nd ed.)” compiles areas where coal could be practically exploited, based on a comprehensive knowledge collected up to the year of issue, identifying main exploited coal fields. For the areas shown thereof together with and without an amount of coal reserves, the former are shown on the Map, with a focus on “those with high probability of exploitation in the future.”

4. Other points to note

- The focus is on reducing the risk of human intrusion for a long period of time, extending to tens of thousands of years or more.
- Since the “Coal Fields of Japan (2nd ed.)” is about 40 years old, it is necessary to bear in mind potential changes from the current situation, either because reserves have been reduced due to subsequent exploitation or coalfields discovered since then are not included in the data.
- It is necessary to note that, since nationwide data is used, the existence of mineral resources is not consistently confirmed in the “areas where the existence of technically exploitable mineral resources with large reserves are shown,” and there may be points where the absence of minerals can be confirmed by conducting a survey.
- In addition, although the “Coal Fields of Japan (2nd ed.)” identifies areas both with and without coal reserves, for those without reserves, it is necessary to confirm this at the time of the disposal site selection survey.
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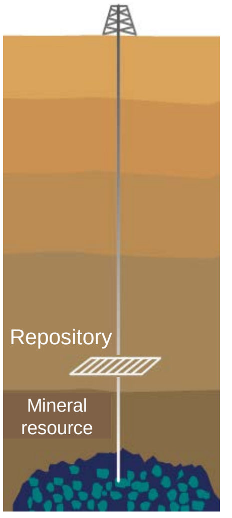

Representation of human intrusion associated with resource exploration

○Process of mapping

1. Reference

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2. Procedures

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- Since mineral resources (oil fields, gas fields, coal fields, and metallic minerals) are identified based on different literature, they are mapped separately.

Mineral resources: Metallic minerals

○ Concept of requirements/criteria

1. and **2.** as for "mineral resources: oil fields/gas fields."

3. Rationale for setting criteria

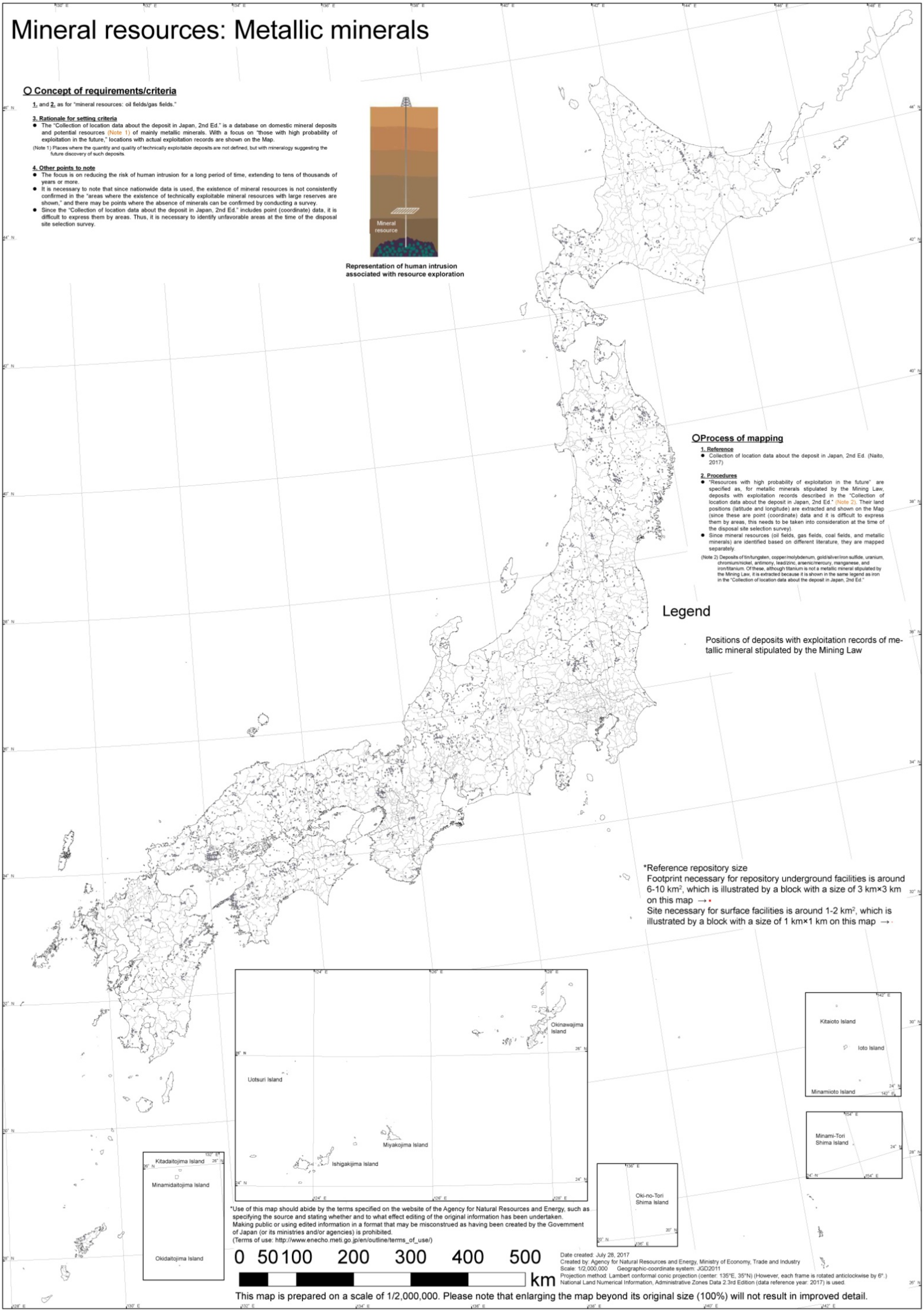
- The "Collection of location data about the deposit in Japan, 2nd Ed." is a database on domestic mineral deposits and potential resources (Note 1) of mainly metallic minerals. With a focus on "those with high probability of exploitation in the future," locations with actual exploitation records are shown on the Map.

(Note 1) Places where the quantity and quality of technically exploitable deposits are not defined, but with mineralogy suggesting the future discovery of such deposits.

4. Other points to note

- The focus is on reducing the risk of human intrusion for a long period of time, extending to tens of thousands of years or more.
- It is necessary to note that since nationwide data is used, the existence of mineral resources is not consistently confirmed in the "areas where the existence of technically exploitable mineral resources with large reserves are shown," and there may be points where the absence of minerals can be confirmed by conducting a survey.
- Since the "Collection of location data about the deposit in Japan, 2nd Ed." includes point (coordinate) data, it is difficult to express them by areas. Thus, it is necessary to identify unfavorable areas at the time of the disposal site selection survey.

Representation of human intrusion associated with resource exploration



○Process of mapping

1. Reference

- Collection of location data about the deposit in Japan, 2nd Ed. (Naito, 2017)

2. Procedures

- "Resources with high probability of exploitation in the future" are specified as, for metallic minerals stipulated by the Mining Law, deposits with exploitation records described in the "Collection of location data about the deposit in Japan, 2nd Ed." (Note 2). Their land positions (latitude and longitude) are extracted and shown on the Map (since these are point (coordinate) data and it is difficult to express them by areas, this needs to be taken into consideration at the time of the disposal site selection survey).
- Since mineral resources (oil fields, gas fields, coal fields, and metallic minerals) are identified based on different literature, they are mapped separately.

(Note 2) Deposits of tin/tungsten, copper/molybdenum, gold/silver/iron sulfide, uranium, chromium/nickel, antimony, lead/zinc, arsenic/mercury, manganese, and iron/titanium. Of these, although titanium is not a metallic mineral stipulated by the Mining Law, it is extracted because it is shown in the same legend as iron in the "Collection of location data about the deposit in Japan, 2nd Ed."

Legend

Positions of deposits with exploitation records of metallic mineral stipulated by the Mining Law

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0 50 100 200 300 400 500 km

Date created: July 28, 2017
Created by: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry
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Mineral resources: Metallic minerals

❍ Concept of requirements/criteria

1. and **2.** as for “mineral resources: oil fields/gas fields.”

3. Rationale for setting criteria

- The “Collection of location data about the deposit in Japan, 2nd Ed.” is a database on domestic mineral deposits and potential resources (Note 1) of mainly metallic minerals. With a focus on “those with high probability of exploitation in the future,” locations with actual exploitation records are shown on the Map.

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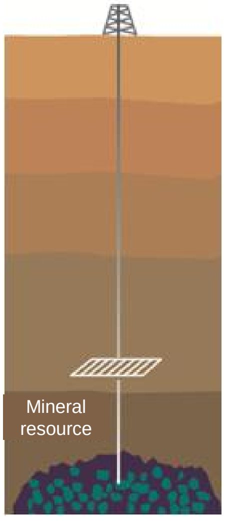
4. Other points to note

- The focus is on reducing the risk of human intrusion for a long period of time, extending to tens of thousands of years or more.
- It is necessary to note that since nationwide data is used, the existence of mineral resources is not consistently confirmed in the “areas where the existence of technically exploitable mineral resources with large reserves are shown,” and there may be points where the absence of minerals can be confirmed by conducting a survey.
- Since the “Collection of location data about the deposit in Japan, 2nd Ed.” includes point (coordinate) data, it is difficult to express them by areas. Thus, it is necessary to identify unfavorable areas at the time of the disposal site selection survey.



Representation of human intrusion associated with resource exploration

❍Process of mapping

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- Collection of location data about the deposit in Japan, 2nd Ed. (Naito, 2017)

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- “Resources with high probability of exploitation in the future” are specified as, for metallic minerals stipulated by the Mining Law, deposits with exploitation records described in the “Collection of location data about the deposit in Japan, 2nd Ed.” (Note 2). Their land positions (latitude and longitude) are extracted and shown on the Map (since these are point (coordinate) data and it is difficult to express them by areas, this needs to be taken into consideration at the time of the disposal site selection survey).
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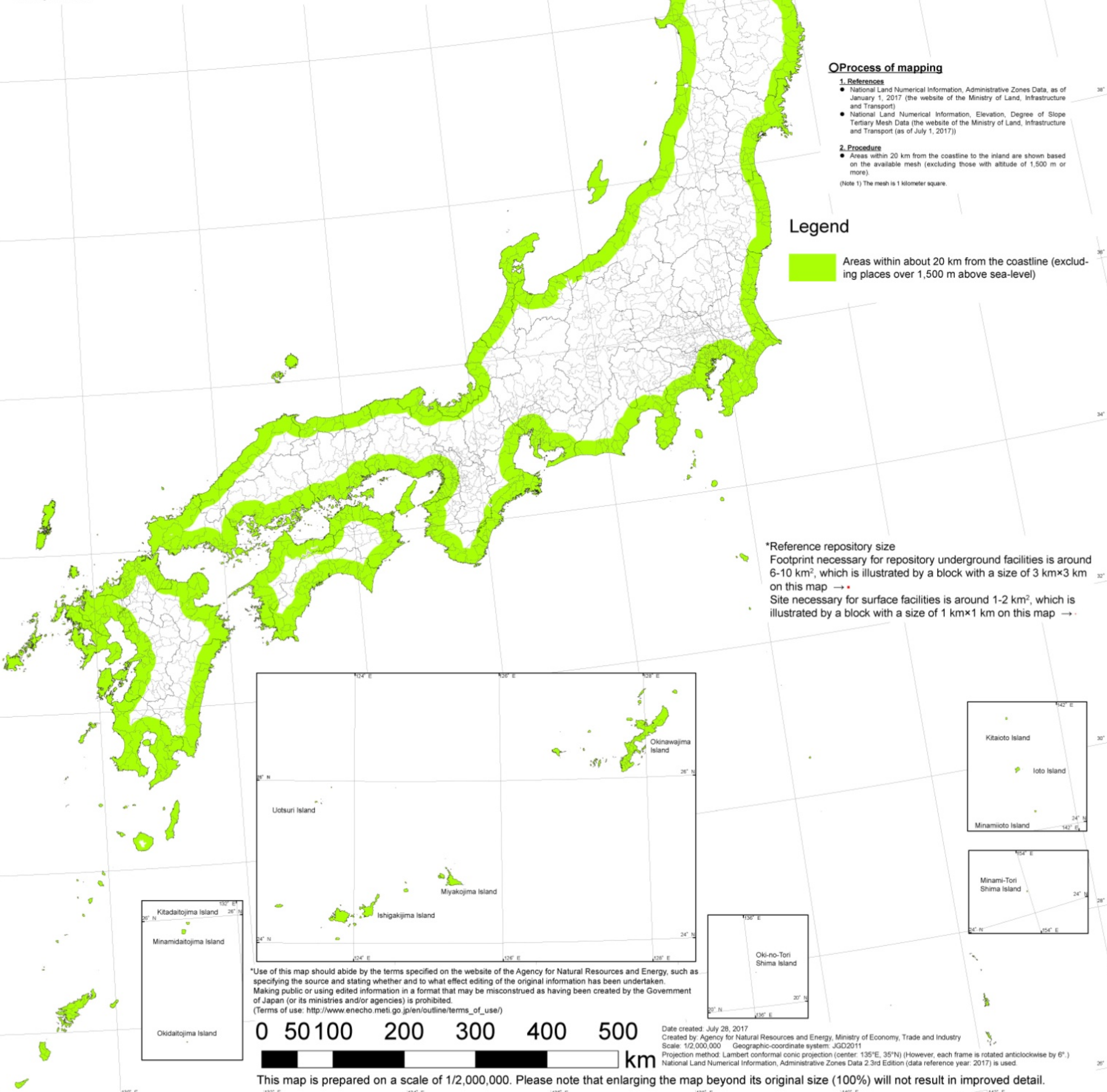
Transportation



○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

Safe waste transportation in terms of radiation exposure and nuclear security.

◆Criteria of preferred area

Areas within about 20 km from the coastline (excluding places over 1,500 m above sea-level).

2. Background

- A transportation container (cask) has the radiation shielding and radionuclide confinement function in the case of collision accidents, fires, etc. Those currently used weigh about 115 tons (including the weight of 28 vitrified waste packages).
- It is estimated that the annual transport requirement is about 1,000 vitrified high level radioactive waste packages and the equivalent of about 3,600 packages of low level radioactive waste for geological disposal (calculated assuming the form and weight of vitrified waste).
- Over a period of several decades or more, annual transportation of a substantial amount of radioactive waste occurs, and it is necessary to comply with regulatory standards concerning the safety of such transportation throughout the entire period.
- From the viewpoint of safety (public exposure) and nuclear security, the following is considered preferable.
  - Marine transport is used for long-distance transportation.
  - Ability to secure a port which is easily maintained and at which waste transport ships can dock.
  - The slopes of roads and railways from the port to the final disposal facility are gentle.
  - From past records and the viewpoint of construction of specialized roads/railways, the distance from a secure coastal port is short.

3. Rationale for setting criteria

- For marine transport, risks of public exposure are small and nuclear security is high based on extensive transportation records. Requirements and criteria are set for land transportation from the port to the final disposal facility, which is considered to have a relatively high risk.
- With reference to transportation records for vitrified waste returned from overseas, it is expected to take approx. 10 hours for inspection, cargo handling, procedures, etc. The transportation plan assumed by the implementing organization specifies, on a conservative basis, a transportation time within 2 hours and hence a transportation distance from the port shorter than about 20 km (10 km/h x 2 hours) is preferable.
- For areas where the distance from a port is short, coastal areas including islands can be considered.
- Among these, even if the distance from a port is within 20 km, areas over 1,500 m above sea-level, which cannot be reached within 20 km at a gradient of about 7.5% based on transportation records, are excluded.

Land transportation from the nearest port

Images of the transportation process

4. Other points to note

- The focus is on safety during transportation, which should be taken into consideration for periods of several decades.
- The upper limit vehicle weight on national roads and freeways is 25 tons (44 tons when traffic permission for special vehicles is obtained; Vehicle Restriction Ordinance based on the Road Act). Therefore, when transport vehicles loaded with casks currently assumed to exceed 100 tons, reinforcement of roadbeds and bridges is needed.

○Process of mapping

1. References

- National Land Numerical Information, Administrative Zones Data, as of January 1, 2017 (the website of the Ministry of Land, Infrastructure and Transport)
- National Land Numerical Information, Elevation, Degree of Slope Tertiary Mesh Data (the website of the Ministry of Land, Infrastructure and Transport (as of July 1, 2017))

2. Procedure

- Areas within 20 km from the coastline to the inland are shown based on the available mesh (excluding those with altitude of 1,500 m or more).

(Note 1) The mesh is 1 kilometer square.

Legend

Areas within about 20 km from the coastline (excluding places over 1,500 m above sea-level)

*Reference repository size

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Site necessary for surface facilities is around 1-2 km², which is illustrated by a block with a size of 1 km×1 km on this map →

0 50 100 200 300 400 500 km

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＜Attachment 11: Explanatory text in figure＞

Transportation

○ Concept of requirements/criteria

1. Requirements (effects on geological disposal)/criteria

◆Requirements

Safe waste transportation in terms of radiation exposure and nuclear security.

◆Criteria of preferred area

Areas within about 20 km from the coastline (excluding places over 1,500 m above sea-level).

2. Background

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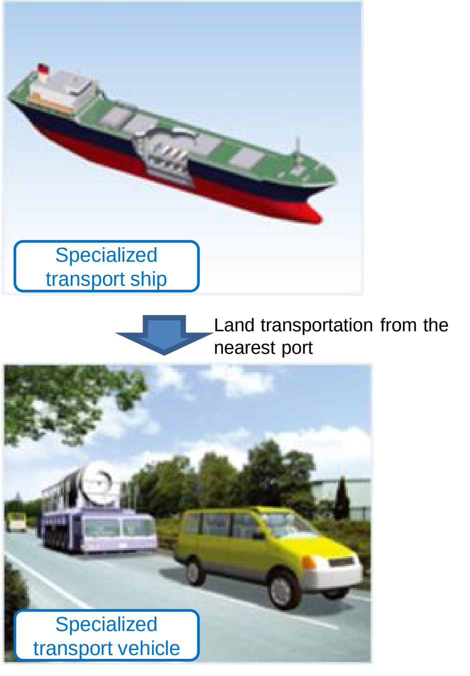

Images of the transportation process

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○Process of mapping

1. References

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- National Land Numerical Information, Elevation, Degree of Slope Tertiary Mesh Data (the website of the Ministry of Land, Infrastructure and Transport (as of July 1, 2017))

2. Procedure

- Areas within 20 km from the coastline to the inland are shown based on the available mesh (excluding those with altitude of 1,500 m or more).

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