Muroto Geopark Japan

Application dossier for nomination as a Geopark with the Global Network

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A. IDENTIFICATION OF THE AREA

A-1. Name of the proposed geopark

Muroto Geopark is the name of the geopark for which member status in the Global Geoparks Network (GGN) is applied through this proposal. Muroto is the name of a region of Shikoku Island, southwestern Japan. Muroto Geopark is found on the Muroto Peninsula, the tip of which is known as Cape Muroto.

The name "Muroto" originates from the ancient habitation in this region. "*Muro*" means "a residential cave in a mountain slope," and "*to*" means "entrance of the house," or "door." In ancient times, Muroto was under the sea water. The caves and rocks formed underwater have been uplifted by repeated earthquakes to generate the present landform above sea level. On such land, people live facing the harsh nature and enjoying the resources provided by the ocean.

As the origin of the name implies, Muroto can be considered as the "door" between the deep ocean and the land. At Muroto Geopark, one can learn firsthand the connection between the ocean and the land, and between the earth and human habitat. In other words, "Muroto" is a name that best represents the theme of this geopark, "Where the ocean and the land meet – the forefront for the birth of new habitable land."

A-2. Geographical and human-geographical features of the proposed geopark

A-2-1. "Where the ocean and the land meet – the forefront for the birth of new habitable land"

Muroto is one of the places in the world where nature frequently shows its fury. In this region, huge earthquakes shake the land about every 100 to 150 years, with huge tsunamis washing the coast away. In between these mega disasters, typhoons[1] roar through the area almost every year. Despite all these challenges, people have lived enriched lives for over 1000 years on the Muroto Peninsula which juts out into the western Pacific Ocean. The Muroto Geopark, located in one of the most active marginal zones worldwide, introduces visitors to the way of life experienced by people living in symbiosis with a harsh natural environment.

At the ocean bottom, 140 km off Cape Muroto, the Philippine Sea Plate has been subducting under the Eurasian Plate. The sediments of the Nankai Trough have been added to the land to form an accretionary complex, part of which is exposed on Cape Muroto for visitors to see and touch. A ceaseless accretion process has caused the sediment layers to tilt nearly vertically (Figure A-1), and former ocean bottom sediments have become part of the land. This illustrates the very process of the early stage of continental crust formation on our planet, which allows us to witness the phenomena at the forefront of the continental growth. The Cape Muroto is being uplifted by 1 to 2 m per 1,000 years, which is among the world's top-class upheaval rates. Lofty terraces have developed near the coastline, with terrace plains on top at 180 m above present sea level. What visitors can see in the geopark is not only the rocks containing the record of events in geologic time scale, such as the accretion process in the past 100 million years and temporary submarine igneous activity accompanying a ridge subduction. Visitors can also observe the evidence of events in human time scale, including minor landforms resulting from the coseismic uplifts at approximately 100 year intervals and remains of submarine organisms pushed up above sea level.

[1] Typhoon: A tropical cyclone which occurs in the northwestern part of the Pacific Ocean between 180° and 100° E.

Figure A-1: Turbidite Layers

The Kuroshio Current (“black current”), the largest warm ocean current in the northwestern Pacific Ocean, is the source of rich underwater biodiversity that also brings violent typhoon wind and rain. The massive amount of rainfall can be hazardous, but is also tapped as drinking water storage for the dry spells in winter. The plate subduction zone on the sea floor off Muroto is one of the most active seismogenic zones on the globe, which repeatedly produces magnitude 8 class earthquakes. However, the land upheavals caused by disastrous earthquakes provide new coastal land. The fruits and vegetables grown on the marine terraces resulting from coseismic uplifts are renowned specialties of this area (Figure A-2). Our ancestors used to worship natural phenomena which can both enrich and destroy their lives. The legacy of the sense of awe toward the nature can be found in the historical townscape and traditional folk performances in the community (Figure A-3). We have lived our lives in this area, being supported by a warm climate and diverse ecosystem, appreciating the features of the earth beneath our feet.

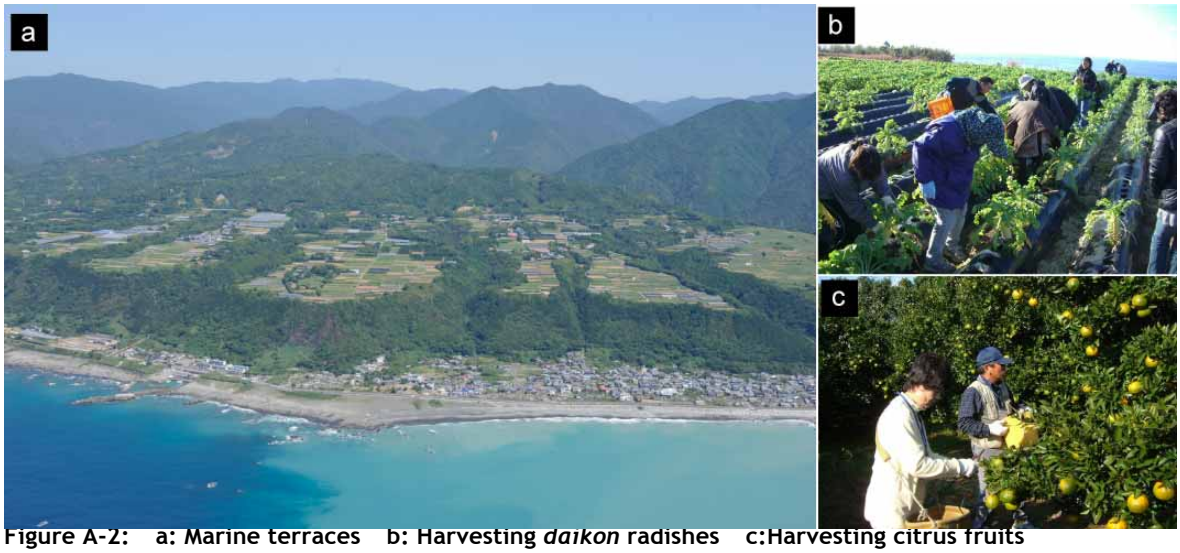


Figure A-2: a: Marine terraces b: Harvesting *daikon* radishes c:Harvesting citrus fruits

For the residents of Muroto, natural disasters are a serious life-threatening issue. Community awareness towards disaster prevention as well as the level of community education on the issue are higher in this city than anywhere else in Japan. At schools and through various media, community members have been educated on the plate tectonics theory and the mechanism of earthquakes and tsunamis. Efforts have been made to improve the earthquake resistances of buildings and to install disaster information distribution systems in the community. The city government and residents have cooperated to conduct evacuation drills for years. The ingenuity to minimize the damage of natural disasters to enjoy the nature’s blessing is reflected on the traditional architectures and the lifestyles in the area. We expect Muroto Geopark to be more than just an educational source on geology such as accretion processes at plate subduction zones. We believe that it has the potential to serve as a world-class model for disaster prevention against earthquakes, tsunamis and typhoons.

Figure A-3: Traditional festivals a: Ondamatsuri festival b: Shittoroto dance

A-2-2. A triangular cape extending into the ocean

The Muroto Geopark is located in the southwestern part of the Japanese island arc in the eastern segment of the Eurasian Continent. Among the several islands comprising the Japanese Archipelago, Shikoku is the 4th largest island with an area of approximately 18,800 km^2. At the southeastern tip of the island, the Muroto Peninsula juts out into the Pacific Ocean, which is the location of this proposed geopark (Figure A-4a).

Muroto Geopark encompasses the entire administrative district of Muroto city, Kochi prefecture[2]. The geopark covers an area of 248.3 km^2, stretching 18.6 km east to west, 27 km north to south, with 53.3 km of coastline.

Mountainous areas cover 87% of the Muroto Peninsula, and the mountain range at the northern margin of the Muroto city is nearly 1000 m high. The steep landforms developed in this coastal area indicate that abrupt land upheavals have taken place in the past.

The east and west side of the cape possess different topographical features. Divided by the N-S axis running through the tip of Cape Muroto, the east coast consists of a steep fault scarp plunging into the deep ocean. On the west coast, marine terraces have developed. Flat areas only account for 13% of the land. The narrow flatland lying between the coast and the mountains is where life and local economic activities take place (Figure A-4b).

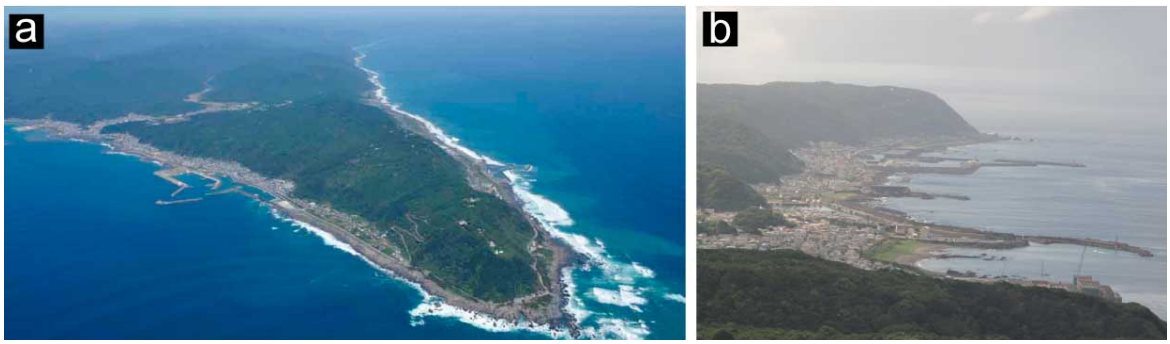


Figure A-4 a: Aerial photo of the Muroto Peninsula b: Urban area

[2] Japanese administrative units consist of 47 prefectures, subdivided into smaller units including cities, towns and villages.

A-2-3. Warm Climate and typhoons

Figure A-5: Subtropical vegetation a: Hibiscus b: *Ficus superba* (protected by national government) c: *Musa basjoo*

Muroto belongs to, as most other areas in Japan do, the "humid subtropical climate (Cfa)"of Köppen Climate Classification. Because of the Kuroshio Current in the Pacific Ocean flowing in the sea area south of this geopark, the climate is fairly temperate as compared to most other places in Japan. In addition, the Shikoku mountain range to the north blocks monsoons, resulting in relatively warm winters with snow seldom occurring. The yearly average temperature is 17°C. This area also belongs to a region of high rainfall with an average of 2,520.5 mm a year. The high temperature and humidity are suitable for agriculture and forestry, and subtropical vegetation is found around Cape Muroto (Figure A-5).

Muroto is also notorious for being subject to frequent typhoons which occur in the Philippine Sea. The typhoons often cause serious damage with heavy rain and wind in summer and autumn. Records show several strong typhoons in the past designated "Muroto Typhoons." The one which affected this area on September 16th, 1961 was a storm with a maximum instantaneous wind speed of over 84.5 m/s, the second highest record in Japan[3] (Chronological Scientific Table, 2010) (Figure A-6).

Figure A-6: Typhoon wave

A-2-4. Kukai, a priest who came to Muroto in search of a harsh training site

The landform and climate of the area, which comprise Muroto Geopark now, may have largely influenced the ascetic training of a priest, Kukai[4]. Buddhist priests undergo severe ascetic trainings in order to discipline their body and mind. The Shikoku Island with its harsh climate and landforms has been chosen by many disciples as a training site for centuries. Kukai undertook his training mainly in Shikoku Island about 1,200 years ago and founded the Shingon school (a Japanese school) of Buddhism. His training in Muroto is mentioned in old literatures.

The Shikoku 88 Temples Pilgrimage is a journey to visit the sites associated with Kukai, which was originally popular among his enthusiastic followers. Currently, many people, including those from different countries and religious background visit Shikoku as pilgrims in search of inner peace. As a

[3] It was the maximum speed that the aerovane at the local weather station was capable of measuring.

[4] **Kukai:** 774-835. A Japanese priest who founded Shingon school of Buddhism after studying in China. Posthumous name is Kobo Daishi.

result, the 88 temples in Shikoku Island, including those in Muroto, have become the most popular pilgrimage site in Japan among general public.

The rough landforms of the Muroto Geopark area have been formed by the uplift of Cape Muroto. The east coast of the cape, with ragged landscape resulted from the actions of submarine active faults, is one of the hardest parts of the entire pilgrimage route. The Hotsumisakiji Temple in Muroto Geopark, located on top of a marine terrace at the tip of Cape Muroto, is the first temple for the pilgrims walking from neighboring Tokushima prefecture to see after a long, tough journey (Figure A-7). Another temple included in the pilgrimage, Kongo choji Temple is also on top of a marine terrace on the west coast of the cape.

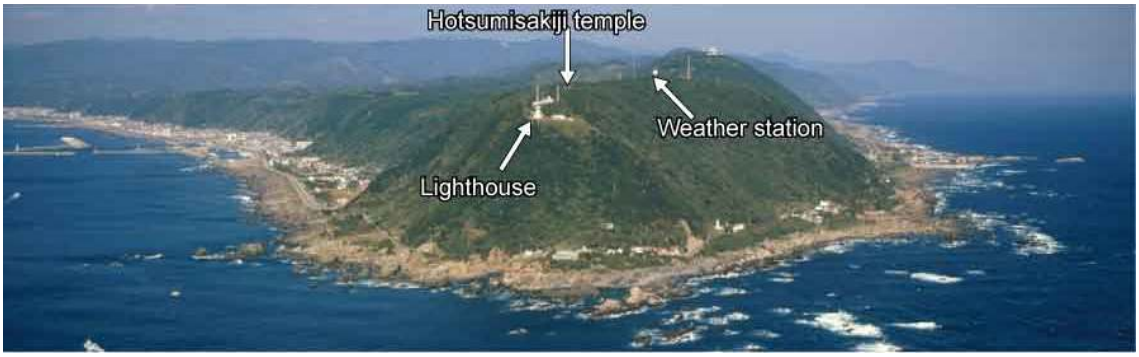
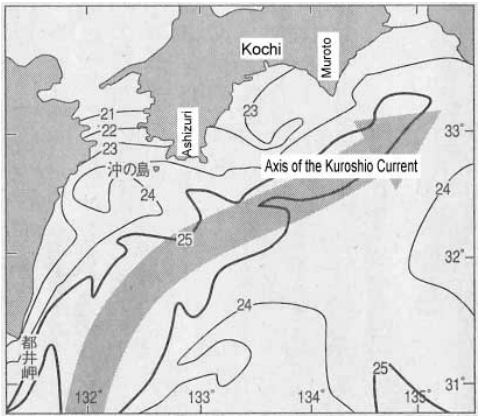


Figure A-7: View of Cape Muroto (from the south)

A-2-5. The long and continuous relationship between culture, history and nature

The rich ecosystem of the region has sustained the relationship between Muroto's culture and ocean creatures such as dolphins and whales. The biodiversity in the area around the Muroto Peninsula has been strongly influenced by the warm ocean current called Kuroshio, which flows eastward in the ocean south of the peninsula. The residents in Kochi prefecture are highly interested in marine issues. An example of this is a local newspaper, Kochi Newspaper, which reports the changes in water direction and distribution of water temperature of the nearby warm ocean current daily (Figure A-8). The waters around the Muroto Peninsula are a habitat for various marine life such as whales, dolphins and sharks. The biodiversity in this ocean area has been provided by the differing water depth on each side of the cape, which resulted from the formation process of Cape Muroto. For example, right whales live in the relatively shallow sea on the west side of the cape, whereas sperm whales live in the deep sea on the east side.



igure A-8: Axis of the Kurioshio Current and ocean water distribution off Muroto and surrounding regions of Shikoku Island, southwest Japan (Kochi Newspaper 2010, November, 18, modified)

Muroto has a long relationship with these ocean mammals. Whale hunting had been conducted in the past to secure a source of protein and also as training of navy trainees. Since local economic development was based on the commercial whaling in the past, its influence has been reflected on the art, culture and festivals in the community. The legacy in the form of art is highly valued in Muroto. The examples include restored traditional whale boats and paintings illustrating the past whaling practices (Figure A-9a). Moreover, traditional ceremonies have been held yearly to pray for prosperous fishing or to grieve for the hunted whales (Figure A-9a). Currently, since commercial

whaling is now banned, whales and dolphins are important resources for biological and environmental education and tourism in this region (Figure A-10).

Figure A-9: a: A painting illustrating past whaling practice b: Whale boat racing

The community assets also include many traditional festive events passed down for generations, reflecting the unique culture of each community. For example, Ondamatsuri festival in Kiragawa town, held at Hachimangu shrine is widely known as a “fertility festival” which has been designated as a Significant Intangible Folk Cultural Asset by the national government. Female participants wishing to conceive fight over a wooden “fertility doll.” Another example is “Sakihama Niwaka,” a humorous, satirical skit with a lot of improvisation, also a Significant Intangible Folk Cultural Asset designated by the prefectural government (Figure A-11). These traditional festivals carried out by members of different generations have helped strengthen ties in the community.

Figure A-10: a: Whale watching b: Muroto dolphin center

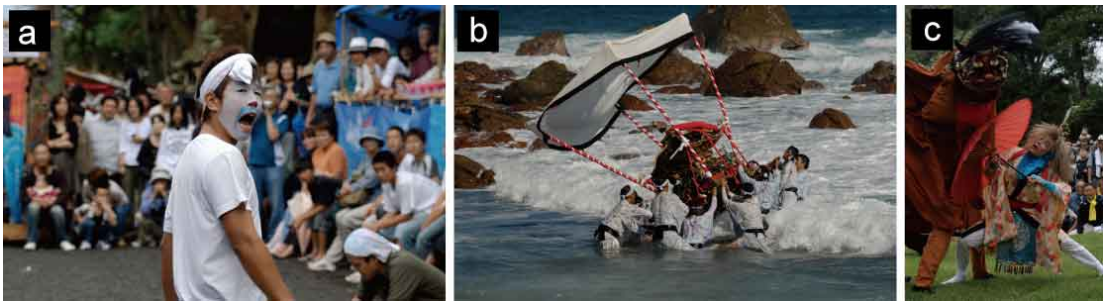


Figure A-11: Traditional festivals

A-2-6. Population and transportation

The national population census in 2005 reported the population of Muroto city as 17,490 and the number of households, 7,574. The population has been showing an over 30% decrease since 1985.

This area can be accessed by public transportation or by car. The public transportation includes plane, train and bus service, both local and long-distance. Various combinations are available for visitors to choose from.

For those coming from abroad, plane is the most recommended mode of transportation. The route includes a transfer at either Narita or Haneda Airport in Tokyo, the capital of Japan. Between Haneda and Kochi Ryoma Airport, nine flights operate daily, and the flight takes approximately an hour and half. Visitors arriving via Narita need to take a bus or train to Haneda for connecting to the domestic flights to Kochi. The main road that connects Kochi Ryoma Airport and Muroto is the national road Route 55, and the travel time is approximately 1 hour and half by car.

To visit Muroto from various places in Japan, another choice is public transportation by surface. Visitors coming by train need to combine the train service with the local bus service to reach the final destination. From Japan Railways (JR) Kochi station, which is located in the prefectural capital, Kochi city, the combination of JR Tosa Kuroshio-line and bus service will take visitors to Muroto city. Coming from Tokushima prefecture, the northeast neighbor of Kochi prefecture, a combination of train services on the JR Asa line and bus service for the rest will bring visitors to Muroto. Express bus service is available from Tokyo and several metropolitan cities. (From Osaka, there is a direct bus service to Muroto.) To access Muroto by car, visitors need to get off the Kochi Expressway at Nankoku Interchange, and drive on the national road Route 55 to the east for approximately1 hour and 40 minutes. From Kochi city, the travel time is about 2 hours. Rental car and taxi services are also available.

A-3. Organization in charge and management structure

A-3-1. Administrative body

Muroto Geopark is run by the Muroto Geopark Promotion Committee, which was established in June 2008 through the collaboration of the government, universities, tourism groups, business groups, research organizations, schools, citizen's groups, tourism agency and local residents, with the mayor of Muroto city as the Chairperson. Currently this committee is a voluntary organization, consisting of 14 groups and 47 individual members (as of October 2010). Future acquisition of corporate status is being pursued.

In addition to the annual assemblies, periodic board meetings are called as needed, and the overall direction is decided at the annual assembly.

A-3-2. Board

The board comprises the members shown in the organizational chart (Figure A-12). At the board meetings, decisions are made on each business project and roles are allotted for promotion activities. Board members enjoy a term of two years.

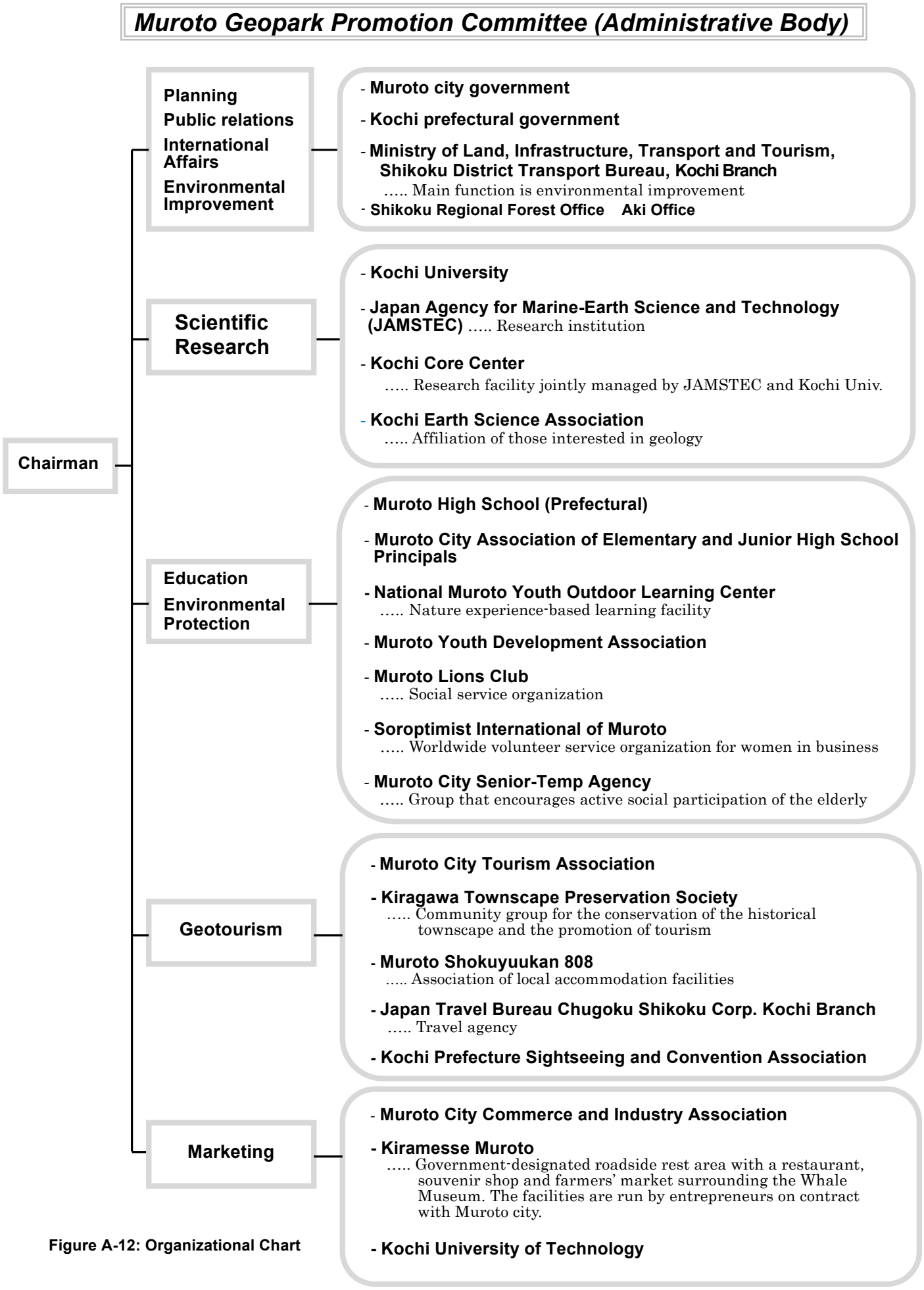


Figure A-12: Organizational Chart

A-3-3. Secretariat

Secretariat of the Muroto Geopark Promotion Committee, consisting of full-time staff members for the promotion of geopark activities, is a part of the Planning and Finance Department of Muroto city. As of November 2010, six staff members belong to the secretariat: two city employees, one visiting staff from Kochi prefectural office, a geologist (qualified with Ph.D. degree) a translator and a clerical assistant.

A-3-4. Activities

The activities of Muroto Geopark are based on a master plan and an action plan. The master plan covers the term of ten fiscal years from 2010 to 2019, while the action plan covers the three fiscal years from 2010 to 2012. These plans will be renewed at the completion of the initial terms. The action plan will be executed with periodical evaluation and verification based on Plan-Do-Check-Act (PDCA) cycle. The key components of the plan are as follows:

1) Protection of the community heritage
   - -to publicize the protection laws
   - -to encourage cleanup activities and surveillance

2) Education and research
   - -to introduce geopark-related class activities into school curricula
   - -to attract university field trips
   - -to promote research activities

3) Geotourism
   - -to extend the tourists' duration of stay by attracting them to many destinations
   - -to train tour guides
   - -to develop activity-based tourism
   - -to collaborate with travel agencies
   - -to promote regional tourism

4) Industrial promotion
   - -to add value to conventional commercial products
   - -to develop new products
   - -to establish a marketing strategy

5) Awareness raising and information distribution
   - -to raise awareness among citizens
   - -to promote disaster prevention education
   - -to conduct public relations activities targeting people inside and outside of the prefecture
   - -to run events and symposiums

6) Administrative body's function
   - -to strengthen the administrative function
   - -to encourage community involvement

7) International contribution
   - -to participate in the Global Geoparks Network and Asia Pacific Geoparks Network (APGN)
   - (Activities include attending international conferences and establishing sister geopark relationships.)

In order to promote the aforesaid activities, the Muroto city government and Kochi prefectural government are providing the Muroto Geopark Promotion Committee with strong support in terms of finance and human resources. The committee draws up contracts with the board member groups and cooperating firms for the effective execution of geopark activities.

The committee abides by public laws, regulations and its bylaws. Geopark activities are also conducted in accordance with the following plans: Industrial Promotion Plan of Kochi prefecture, Muroto city's Comprehensive Development Plan, Plan for the Promotion of Initiative in Areas of Declining Population and Muroto City Environmental Master Plan.

A-3-5. Budget and finance

The Muroto Geopark Promotion Committee is an organization with independent budget and financial management. Its revenue mainly consists of subsidies from the government. Additionally, membership fees from its members and business-derived income are further sources of revenue.

The government subsidies will be the main source of income in the future. The committee also plans to develop its own business such as licensing of the brand (e.g. logo and geopark anime characters), or obtain sponsorship from businesses.

Table A-1: Annual revenue of the Muroto Geopark Promotion Committee

(All figures in Japanese yen)

Fiscal[5] year	Budget	Details			
		Subsidy from Muroto city	Subsidy from Kochi prefecture	Membership fee	Business-derived revenue
2008	128,000	-	-	80,000	48,000
2009	7,172,000	3,629,000	3,414,000	93,000	36,000
2010	17,410,000	6,189,000	10,940,000	93,000	188,000

The government subsidies for fiscal 2009 were used for the development of website, preparation of advertising media including posters and clerical costs of supporting various activities. The revenue from 2010 onwards will be used for preparation of advertising media, payroll costs for specialist personnel, and clerical cost to support various activities. The membership fee is collected from the committee members. The business-derived revenue was generated by geopark-related events.

The revenue from 2011 onwards will be, as it has been, mostly from government subsidies given to the operations necessary for the sustainable development of Muroto Geopark. Also, the committee aims to increase income through its own business operations.

Table A-2: Public Investments

(All figures in Japanese yen)

Fiscal year	Total	Muroto city	Kochi prefecture
2008	1,021,000	1,021,000	-
2009	33,824,000	12,914,000	20,910,000
2010	79,519,000	25,931,000	53,588,000

[5] Japanese fiscal year is from 1st April to 31st March.

The public investment by the local government for fiscal 2008 was used to create a plan for preparing for a potential geopark. The amount allocated for fiscal 2009 consisted of a grant for the above mentioned committee, expenses for the setup/maintenance of signboards, walking trail, parking area, a gallery, and tour guide training. For fiscal 2010, the public investments were allocated for the grant for the committee, expenses for the setup/maintenance of signboards, walking trail and Geopark Information Center, and for tour guide training.

From 2011 onwards, Kochi prefectural government and Muroto city government shall provide strong support, which should lead to the sustainable development of the Muroto Geopark.

A-4. Application Contact Person

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B. GEOLOGICAL HERITAGE

B-1. Location of the proposed Geopark

Muroto Geopark is located at the southern tip of the Muroto Peninsula in eastern Shikoku Island, south-western Japan, and encompasses the administrative district of Muroto City (33°16' N and 134°10' E) (Figure B-1).

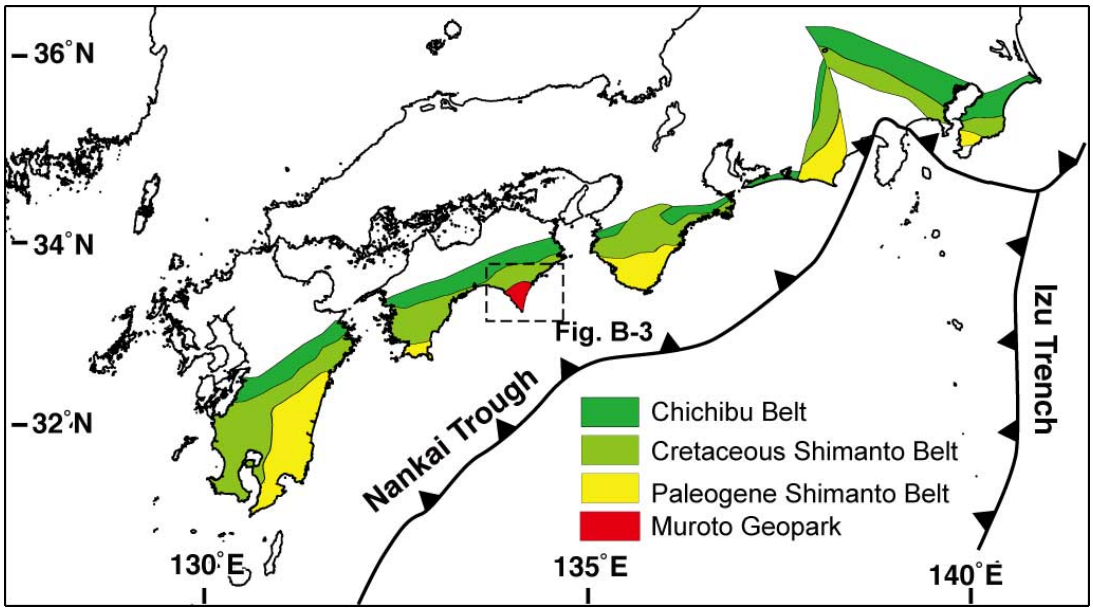

Figure B-1: Regional Map

B-2. General geological description

Muroto Geopark is underlain by accretionary complex that represents continental growth. On the ancient Earth, the evolution of continents began with plate tectonic activities that built island arcs and subsequently led to the formation of accretionary complexes. The foundation of major continents, including the Eurasian, African, American and Australian continents, was built through accretionary processes at subduction zones along convergent plate margins. Even the orogenic movements in the great mountain belts such as Alps or the Himalayas, characterized by continental collision, were preceded by the formation of accretionary complexes. Currently, submarine accretionary complexes occur scattered in the Pacific Rim region, and similar geologic entity is being formed in Alaska, the west coast of North America, Taiwan and the islands in Southeast Asia (Figure B-2). However, on-land accretionary complexes tend to lose their original forms due to later geological processes such as igneous activities, metamorphism, large-scale crustal movements and tectonic erosion, as in northeastern Japan.

At Muroto Geopark, on the other hand, one can clearly observe the original form of an accretionary complex. That is because a sudden change in the age of subducting plate has caused a geological miracle. Since around 100 Ma, accretionary complexes had been forming at the eastern edge of Asia, caused by the subduction of an old oceanic plate. Since around 25 Ma, the subducting older plate was replaced by a younger plate, the Philippine Sea Plate. Younger oceanic plates tend to be less dense than older plates and therefore their subduction process is more powerful in uplifting the continental plate. Due to the subduction of a younger and lighter oceanic plate, the continental plate was elevated to expose the original form of an accretionary complex above sea level (Figure B-3).

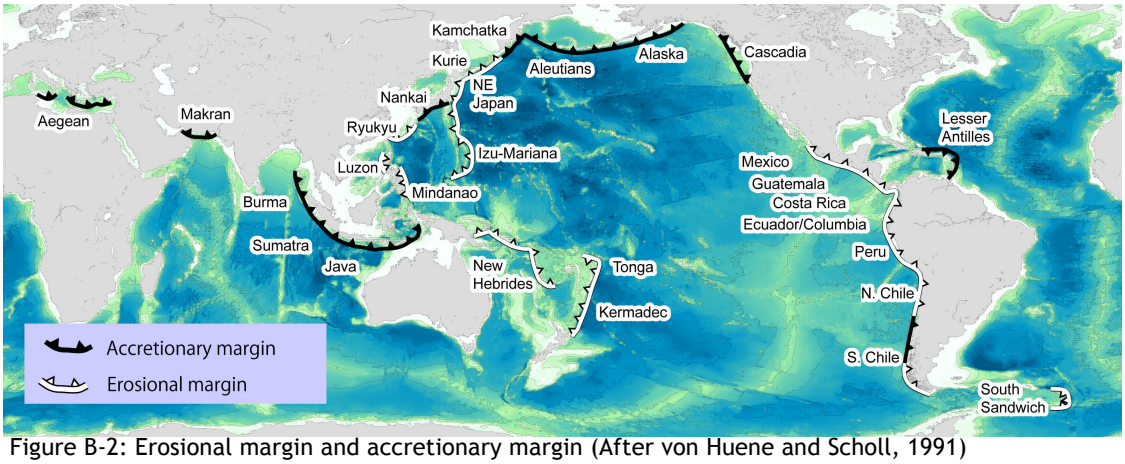

Figure B-2: Erosional margin and accretionary margin (After von Huene and Scholl, 1991)

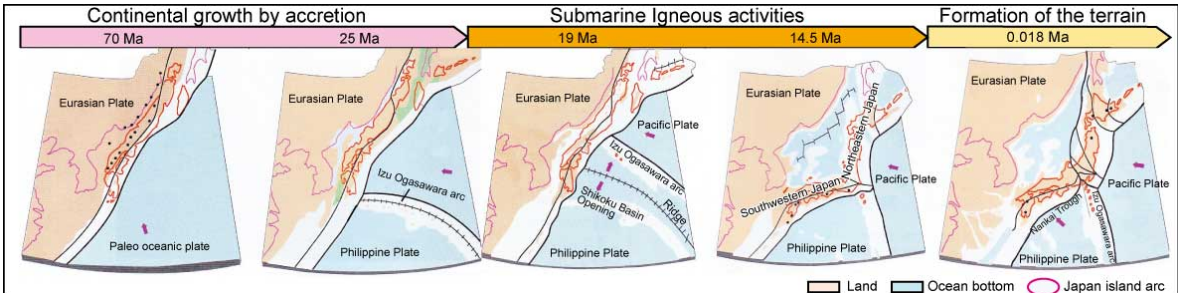

Figure B-3: Developmental history of the East Asian region (After Taira, 1990)

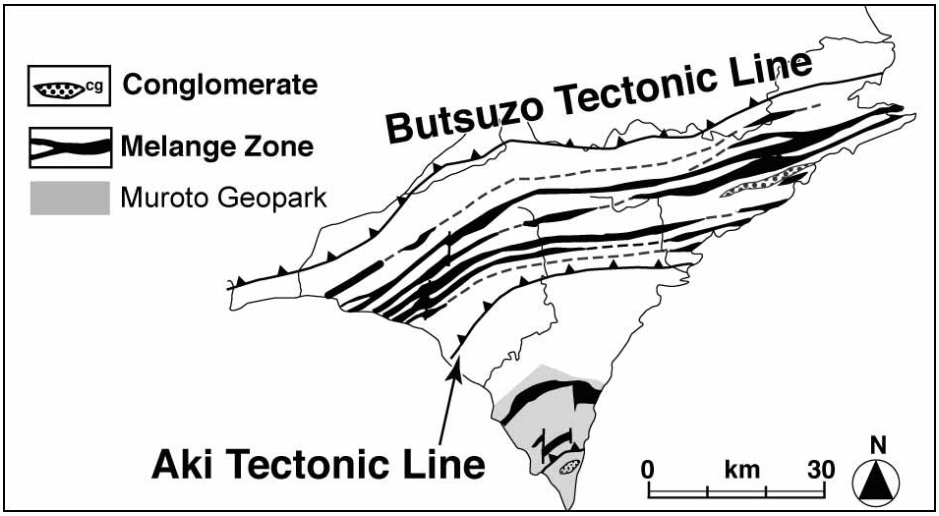

Figure B-4: Geological map The Shimanto Belt in eastern Shikoku (After Taira et al., 1988)

The Japanese Island Arc consists of accretionary complexes from different periods, ranging from Paleozoic to Cenozoic. The early to middle Paleozoic accretionary complexes have undergone metamorphism, while those from late Paleozoic, Jurassic, Cretaceous and Cenozoic Eras are virtually unmetamorphosed and widely distributed. The Permian to Jurassic accretionary complexes belong to the Chichibu Belt, and that from the Cretaceous-Neogene period to the Shimanto Belt, respectively. The complex formed in the period from Neogene to present comprises the seafloor off Southwestern Japan including Muroto.

In the Shikoku Island, a low-angle reverse fault, the Butsuzo Tectonic Line, separates the Chichibu Belt to the north and the Shimanto Belt to the south. The Shimanto Belt is subdivided by the Aki Tectonic Line into two belts: the northern Shimanto Belt which is predominantly Cretaceous and the southern

Shimanto Belt of dominantly Paleogene age (Figure B-1, 4). The Muroto Geopark consists of Paleogene to Neogene formations dissected by several faults (Figure B-5).

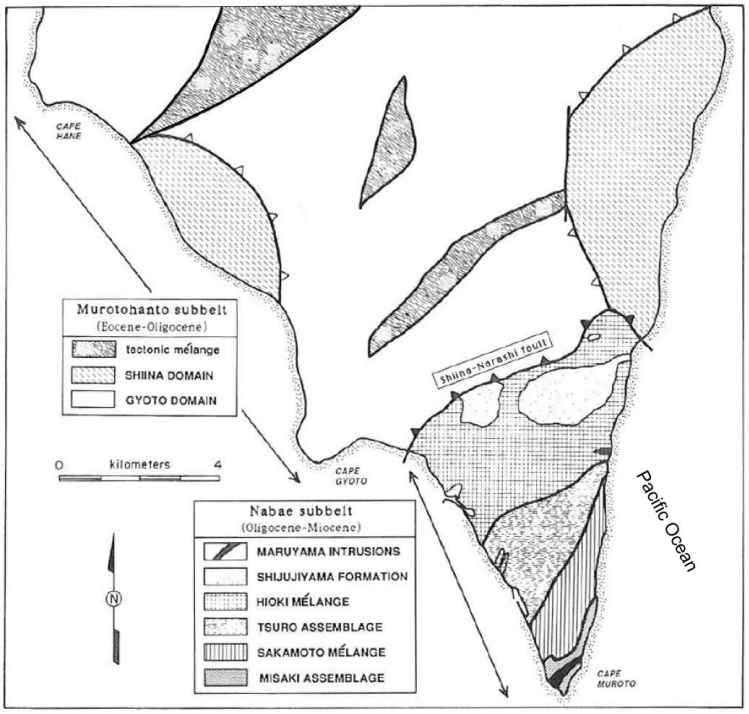

Figure B-5: Tectonostratigraphic units within the Paleogene Shimanto Belt, Muroto Peninsula, Shikoku (After Underwood et al., 1993)

A ridge subduction during the accretion process resulted in igneous activity leading to the formation of gabbroic rocks (e.g. Mizoguchi et al., 2009). This magmatic rock is considered to have intruded at 14.4 ± 0.4 Ma (Rb-Sr biotite whole-rock isochron age: Hamamoto, Sakai, 1987) into the accretionary complex (the Shimanto Belt) which, at that time, was part of the ocean floor (Hoshide et al., 2009). The alternating sandstone and mudstone layers which constitute the accretionary complex, adjacent to the igneous rock, were affected by contact metamorphism. However, the original form of the accretionary complex remained nearly unchanged (Hasebe et al., 1993).

The inverted triangular shape of the Muroto Peninsula is related to the elevation attained through the accretionary growth. The whole area encompassing the Muroto Geopark is included in an east-west compressional field (Awata and Sugiyama, 1989; Okamura, 1990). In Shikoku Island, the tectonic movements uplifted the Muroto Peninsula and Cape Ashizuri into anticlinal structures and the Tosa Bay into a synclinal structure. The upheaval of Cape Muroto is best represented by the Quaternary marine terraces on the west coast of the cape. Several wave-cut platforms of varying heights have been forming in this region since 160,000 years ago. The highest plain reaches the height of 180 m above the present sea level. Each of the platforms here was formed by the glacial-interglacial sea level changes and coseismic uplifts (Sakai, 2003).

The recurrence of the earthquakes in this region still continues to date at an interval of 100 to 150 years. In 1946, a large earthquake of magnitude 8 (Nankai Earthquake) and associated tsunami affected southwestern Japan. The probability of such an earthquake occurring within the next 30 years is expected to be 60 % (Headquarters for Earthquake Research Promotion, 2004). To establish this earthquake prediction model, studies conducted in the Muroto Geopark have made a great contribution. The studies include ^{14}C dating on the fossils of tube worms (*Pomatoleios kraussii*), which inhabit near the sea surface (Maemoku, 2001), as well as the detailed record of tidal data at Murotsu Port (Murotsu Port site) (Shimazaki and Nakata, 1980).

It has been noted recently that the occurrence of earthquakes is closely related to the formation of accretionary complex (Hyndman et al., 1993; Moore and Saffer, 2001; Ikesawa et al., 2003). Subsequently, intensive research studies were conducted as part of an international project both on-land and underwater. The project, Integrated Ocean Drilling Program (IODP) is aimed to better understand the mechanism of accretion and relationship to earthquakes at the subduction zone. Investigation through acoustic exploration or drilling projects at the Nankai Trough has unraveled the details of the structure of underwater accretionary complexes (e.g. Park et al., 2002ab; Kodaira et al., 2000; Taira et al., 1993). In addition, establishment of Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET) started as a national project, which is an improvement in the system of detailed measurement of the Nankai Earthquakes. We expect these latest research findings to further improve the understanding of the geological processes in the Muroto Geopark.

B-3. Listing and description of geological sites

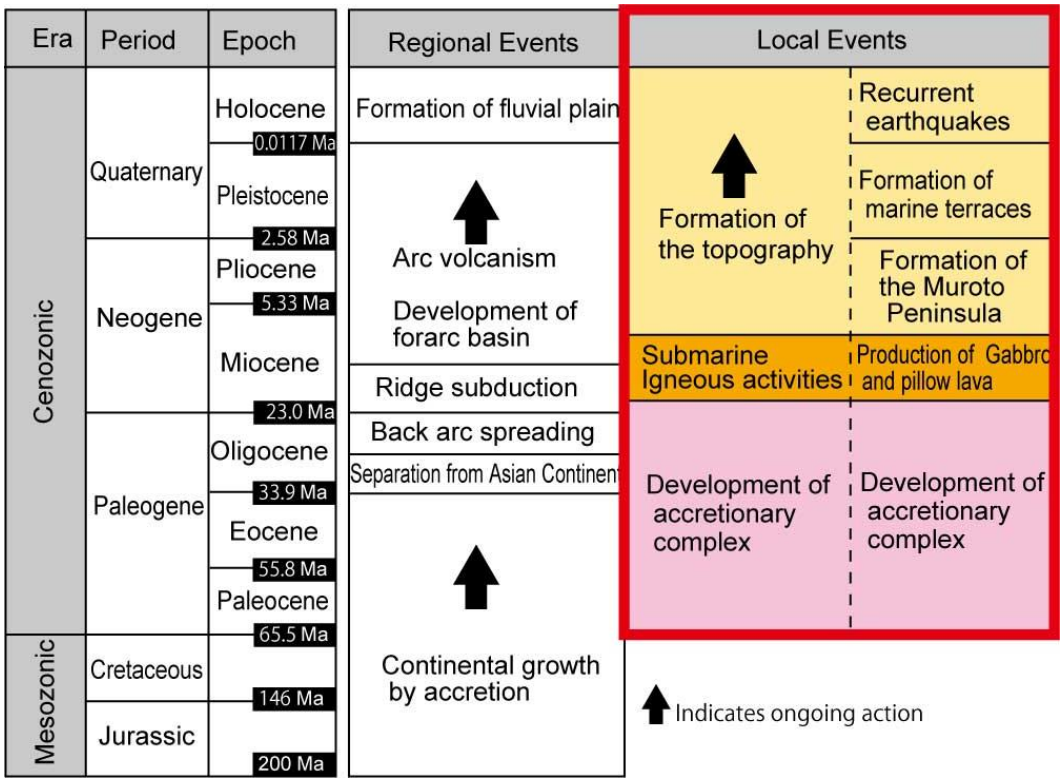

Table B-1 Geologic Time Table, history of development of Japan and the geoheritage in the Muroto Geopark

We designate “geosites” as areas that can be clearly defined geographically, and explained from the viewpoints of geology, geomorphology and human-geography. Our geosites are classified into three groups under these themes: 1) continental growth by accretion, 2) submarine igneous activities and 3) formation of the topography, based on the developmental stage of the geoheritage in the Muroto Geopark (Table B-1). The theme, or the “story” that conveys the theme of each geosite, derived from more than one point of specific interest encompassed in the site. In addition to geological and geomorphological heritage, the points include those of cultural, historical and industrial interest as well as tourism-related facilities.

The Muroto Geopark possesses a total of 22 geosites (from A to Z in Figure B-6). Among these, the sites of geological and geomorphological values are listed below in this section. The significance of each site is described from the viewpoint of the range of its influence (international, regional and local) and its application (scientific, educational and tourism) in the table. The scientific value of each geosite is further described in B-4-1 to 5, with indication of the related points of interest at the end in alphabet letters.
The description of non-geological sites is presented in C-4.

[Continental growth by accretion]

Geosite	Notes	Significance	Application
A: Cape Hane	Index fossils as indicators of the depositional environment during the accretionary complex formation (Paleogene trace fossils of bivalves, etc.) can be observed.	International	Scientific Educational
B: Nobori Formation	Marine sediments from the late period of Early Pliocene to the early period of Late Pliocene (4.2 – 3.21 or 3.12 Ma) can be found, containing fossils of shellfish, shark teeth or fish otoliths.	Local	Scientific Educational
F: Gyodo-Kuromi Coast	Accretionary complex composed of marine sediments deposited approximately 50 Ma is distributed. Accretionary features observed here include ripple marks, sand dykes (evidence of liquefaction) and slump structures.	International	Scientific Educational Tourism
K:Nabae-Sakamoto Beach	One can observe the sedimentary mélange which carry the imprints of submarine landslide caused by earthquakes during accretionary complex formation.	Local	Scientific Educational
M: Cape Muroto	An accretionary complex which was deposited at approximately 25 Ma and an igneous sill (gabbro complex) that intruded 14 Ma are distributed. Various evidence of coseismic uplifts by Nankai Earthquakes is observed. “The forefront for the birth of new habitable land.”	International	Scientific Educational Tourism
Q: Mt. Shijuji	Sedimentary rock covering the accretionary complex. One can observe the sedimentary mélange which recorded the actions of submarine landslide caused by earthquakes during accretionary complex formation. Also, pyroclastic rocks from submarine volcanic activities can be found.	Local	Educational Tourism

[Submarine Igneous activities]

Geosite	Notes	Significance	Application
M: Cape Muroto	The gabbro complex (plutonic rock) in this cape is a sill that intruded into an accretionary complex (Figure B-9a,b,c). Though small-scale, the sill comprises various facies. The magma is considered to have concordantly intruded into the horizontal formation (alternating layers of sand and mud) and solidified. The age is 14.4 ± 0.4 Ma (Hamamoto and Sakai, 1987). It is considered to have been caused by a ridge subduction.	International	Scientific Educational Tourism
R:Hioki-Maruyama Coast	Pillow lava from the eruption at the ocean bottom at 14 Ma. Most pillow lavas (volcanic rock) are formed when basaltic magma erupted from the sea floor. It develops in a unique tube shape, and forms a mass that resembles accumulated pillows.	International	Scientific Educational Tourism
S: Sakihama Town	Pillow lava is observed in mélange.	Local	Scientific

[Formation of the topography]

Geosite	Notes	Significance	Application
C: Hazeyama-Nishiyama Plateau	Marine terraces formed by the Quaternary glacial-interglacial sea level changes and coseismic uplifts.	International	Scientific Educational Tourism
G: Sakiyama Plateau	Marine terraces formed by the Quaternary glacial-interglacial sea level changes and coseismic uplifts. National MUROTO Youth Outdoor Learning Center is located on the terrace here.	International	Scientific Educational Tourism
J: Murotsu Port	Re-excavated several times as repeated earthquakes made the port shallower. Detailed observation records kept at this port helped to prove the recurrence of earthquakes, thus contributing to the establishment of earthquake prediction models.	International	Scientific Educational Tourism
M: Cape Muroto	An accretionary complex which was deposited at approximately 25 Ma and an igneous sill (gabbro complex) that intruded 14 Ma are distributed. Various evidence of coseismic uplifts by Nankai Earthquakes is observed. "The forefront for the birth of new habitable land."	International	Scientific Educational Tourism
O: Deep Sea Water	The east coast of Cape Muroto consists of a steep fault scarp plunging into the deep ocean. Deep sea water upwells along this fault scarp, allowing the harvesting at a relatively shallow point that is close to the shore.	Regional	Scientific Educational Tourism
P: Muroto Skyline (Scenic road leading up to the top of Cape Muroto)	Driving up this road, one can observe the difference in topography on the east and the west side of Cape Muroto. When Muroto Typhoon hit this area, the meteorological observatory on top of Cape Muroto measured a maximum instantaneous wind speed, which became the second highest record in Japan.	International	Educational Tourism
U: Kanagi Landslide	This landslide site covers a total area of 47 ha, at the relative elevation of 470 m. The debris flow deposit was estimated to be 8,500,000 m^3. According to some old document, the landslide was caused either by a strong earthquake in 1707 or the heavy rain of 1746.	Local	Scientific
V: Meoto-iwa Rock (Married Couple Rock)	Spectacular Tafoni formed by salt weathering can be observed.	Local	Scientific Tourism

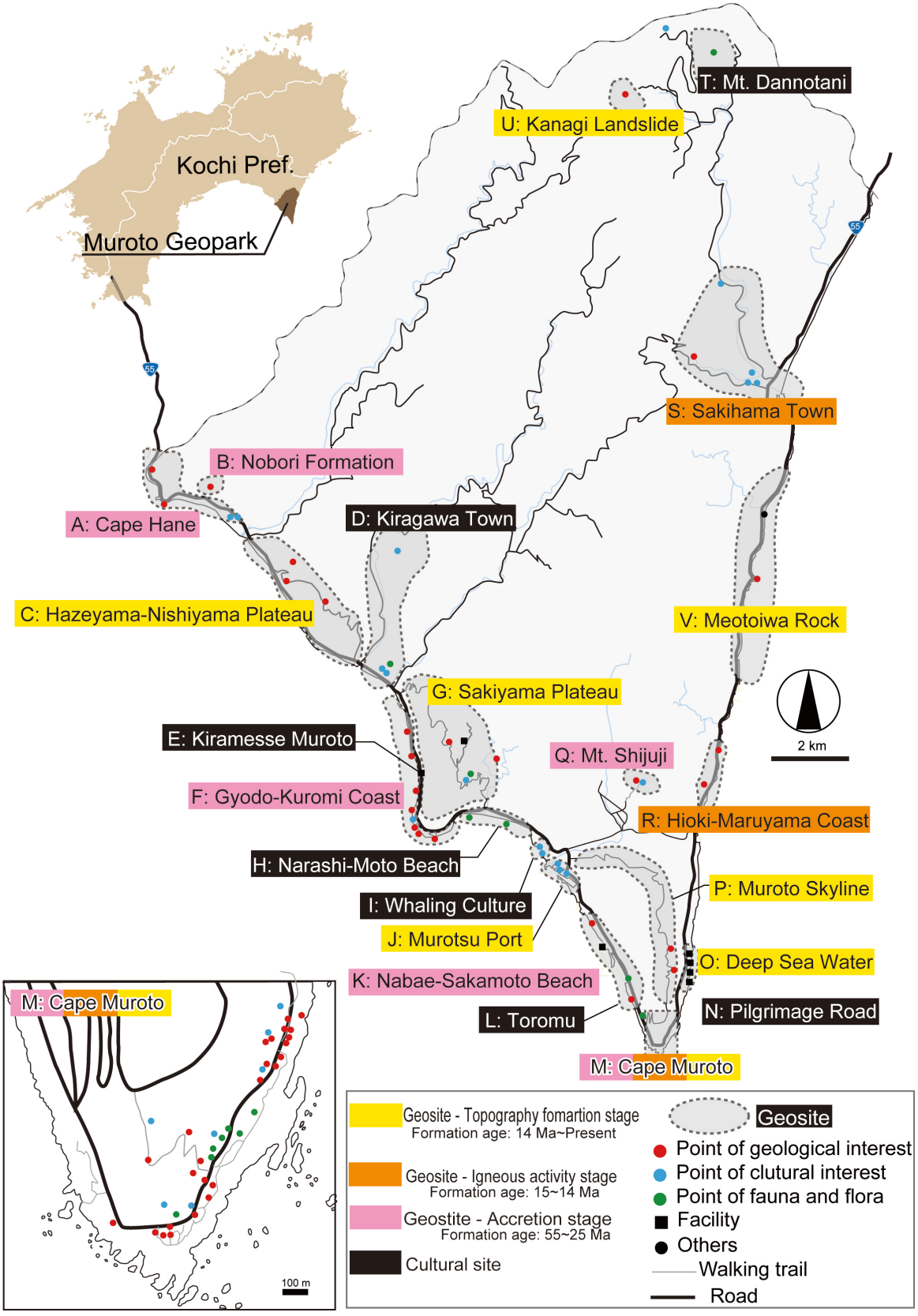

Figure B-6: Site map of Muroto Geopark

B-4.The scientific values of geosites

Cape Muroto retains the record of dynamic movements of the earth which resulted from the motion of tectonic plates. The top layer of the Earth is broken into a number of pieces, and tectonic “plates” refer to the crust of the Earth together with the upper mantle region comprising a thickness of approximately 100 km. The current day globe is comprised of more than ten tectonic plates and these plates are in constant motion. The plate boundaries are classified into: divergent (where continents rift apart), convergent (where collision or subduction occurs) and transform (where one plate slides past the other) boundaries. These plate boundaries are the major regions of igneous activities and continental growth (orogenic movement) on the globe. The Japanese Island Arc is located at a subduction zone. In most cases, the subduction zone is a region where an oceanic plate meets with a continental plate or another oceanic plate. The denser oceanic plate slides under the other plate and sinks into the mantle. The energy generated from the motion of these two plates is transformed as earthquakes, and the various associated tectonic and magmatic activities lead to continent formation (orogenic movement). Muroto Geopark provides an excellent example for these processes.

The explanation of the background of our geosites involves three geologic stages: 1) formation of the accretionary complex, 2) igneous activities and 3) topography formation accompanying the plate subduction. Other crucial factors are the expected large-scale earthquakes, as well as the disaster and blessings from the sky and the ocean. These are closely related to the various earth-phenomena in different time scales, ranging from several million years (e.g. plate motions) to over several tens of seconds (e.g. earthquakes).

Leading studies in earth sciences focus on ”the past”, that is retained in the ground of Muroto in the present case, and “the present”, which can be observed at the bottom of the ocean off Muroto. Studies on the mechanism of generation of earthquakes and tsunamis are among the most active research fields in the world. Such studies have been conducted on Muroto’s geology and the Nankai Trough off the coast of Muroto. The research findings are expected to serve as the basis of the information necessary for minimizing the damage from the earthquakes and tsunamis in the future.

Geological processes occur in time scales that are beyond that of human lives, making it difficult for us to relate them to our daily living. However, our lives are undoubtedly influenced by those processes. We benefit from them, and simultaneously, face the risk of natural disasters. The geosites in the Muroto Geopark possess significantly valuable and useful geoheritage which leads visitors to understand how active our planet Earth is.

What had occurred in the past and what will occur in the future in a region “where the ocean and the land meet?” How can the human civilization co-exist with natural disasters simultaneously enjoying the nature’s blessings? The key to these questions lies in Muroto Geopark and at the bottom of the adjacent waters.

B-4-1.The best-documented on-land accretionary complex in the world

Muroto Geopark is the place to observe the best-documented on-land accretionary complex in the world. The accretionary complex is a geologic entity which was added to island arcs during the subduction process of an oceanic plate. The complex may or may not be affected by metamorphism, or if it is, only slightly at a shallow depth underground. The plate tectonics theory explains the accretion process as follows. The oceanic plate is formed at an oceanic ridge where upwelling takes place in the upper mantle. The plate (the ocean bottom) gradually moves away from the ridge and finally subducts at a trench. During this process, various sediments deposit on the basaltic oceanic plate (e.g. basalt observed in our Sakihama site). In the ocean, such sediments include the silicate chert containing radiolarian remains, limestone containing remains of other living organisms, and

sand and mud transported from the continent. It was this concept of accretionary evolution that has enabled the systematic explanation of the continent formation at the subduction zone (Figure B-7).

In the global scenario, accretionary complexes are produced at some of the subduction boundaries but not in all cases (Clift and Vannucchi, 2004; Figure B-2). Most of the evolving accretionary complexes consist of the sand and mud transported from the continent into a trench and accreted back onto the continent that they originated from. This fact suggests two key factors for the evolution of accretionary complexes: that active erosion on land and a channel for sediments to flow into a trench. Active erosion cannot take place on land unless the uplifting rate of the mountain ranges is high and the rainfall is abundant.

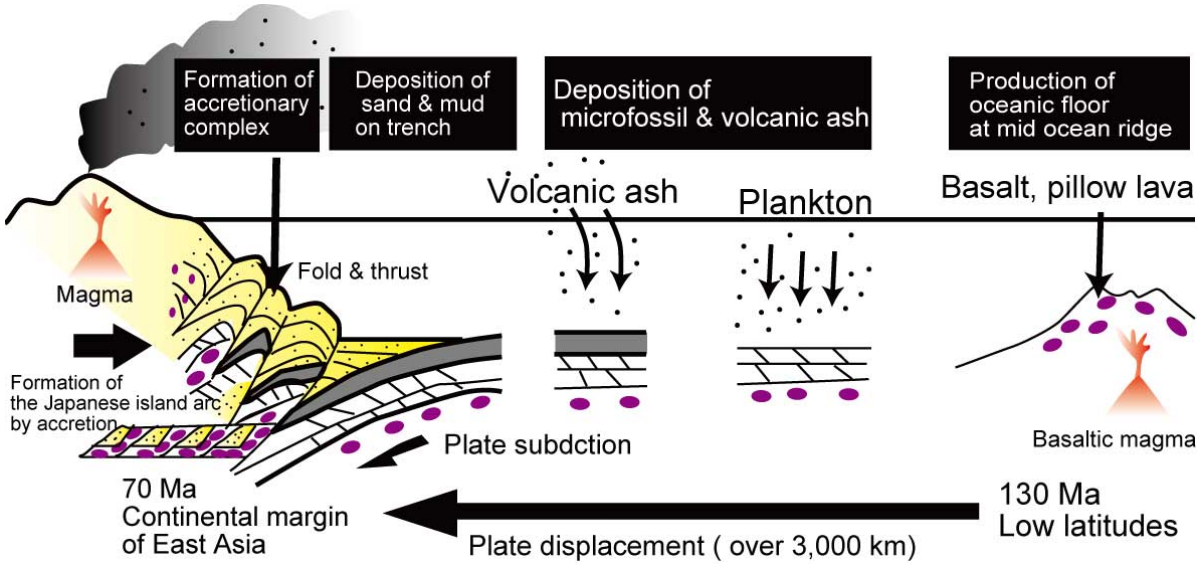

Figure B-7: Evolution of accretionary complex (After Taira et al., 1988)

The accretionary complex which underlies the Muroto Geopark area contains many proofs of the typical sedimentation process that occurs at a subduction zone. Sand and mud delivered through erosion by river water are deposited around the river mouth first. Subsequently, these sediments are stirred up by typhoons or earthquakes and move through submarine valley as a turbidity current, and finally deposit as trench-fill sediments. These are called turbidite layers, i.e., alternated deposits of sand and mud (Figure B-8a).

Sedimentary rocks retain the record of events that occurred before they were solidified. Ripple marks showing the current ripple pattern left on the ocean floor (Figure B-8b) and depositional structures such as cross-lamina and convolution-lamina are found throughout the area, together with bivalve and worm trace fossils (Figure B-8c, e.g. Nara and Ikari, in review). Additionally, when sediment layers at the river mouth tumble down the ocean floor slope, they can be significantly folded, with sand and mud being mixed, with characteristic structures. The alternating sand and mud layers can be complexly folded or torn apart and solidify into slumped layers distributed in the area (Figure B-8d). Also found in this area are sand dykes (Figure B-8e), which are considered to be “fossils of liquefaction” caused by the earthquake-induced vibration.
[Related geosites: A, B, F, K, M, Q]

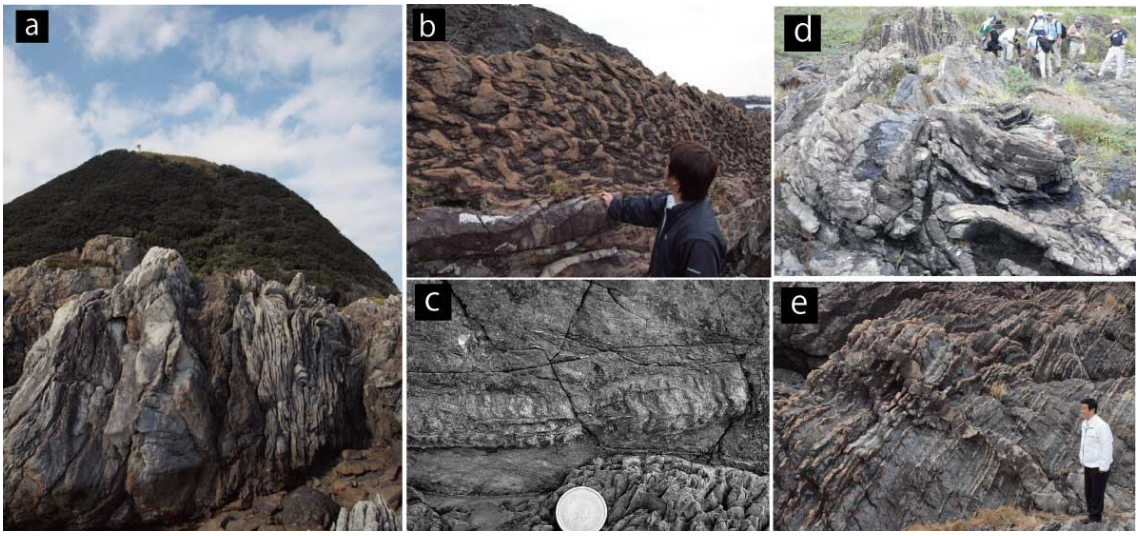

Figure B-8: a: Turbidite layers b: Ripple marks c: Trace fossils d: Slump structure e: Sand dyke

B-4-2. Submarine igneous activities following a ridge subduction

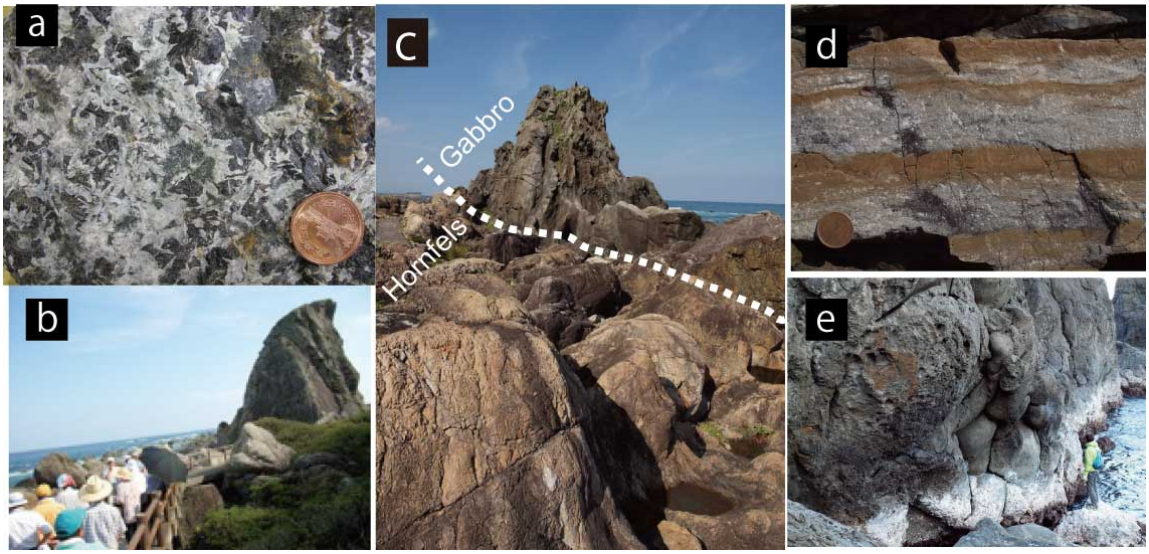

Figure B-9: a: Gabbro b: Visitors enjoying the view of the rocks (gabbro) c: Gabbro and sedimentary rocks metamorphosed into Hornfels d:Hornfels showing the sedimentary structure e: Pillow lava

In Muroto Geopark, one can also observe the proof of submarine igneous activities caused by a ridge subduction, which involved magmatic intrusion into the accretionary complex. Igneous rocks distributed in Cape Muroto are a plutonic rock, gabbro (Figure B-9a, b, c) and volcanic rock, pillow lava (Figure B-9e), both of which were formed approximately 15 to 14 Ma (Hamamoto and Sakai, 1987; Mizoguchi et al., 2009). At approximately 25 to 14 Ma, the rifting Shikoku Basin was subducting beneath the Eurasian Plate in the Philippine Sea (Takahashi, 1986; Shinjoe et al., 2003; Kimura et al., 2005). It was the time when igneous activities and crustal movements were activated throughout Japan. Examples of such events include the opening of the Japan Sea and the rotation of the northeastern and southwestern Japan arcs. In their study on the chemical composition of gabbro in Cape Muroto, Hibbard and Karig (1990) deduced that the submarine igneous activity was closely related to the subduction of a spreading oceanic ridge in the Shikoku Basin. Even today, ridge subduction is confirmed off the coast of Chile, and studies on its relationship with continental growth process are continuing (e.g. Bourgois, 1996).

[Related geosites: M, R]

B-4-3. Development of a dynamic topography

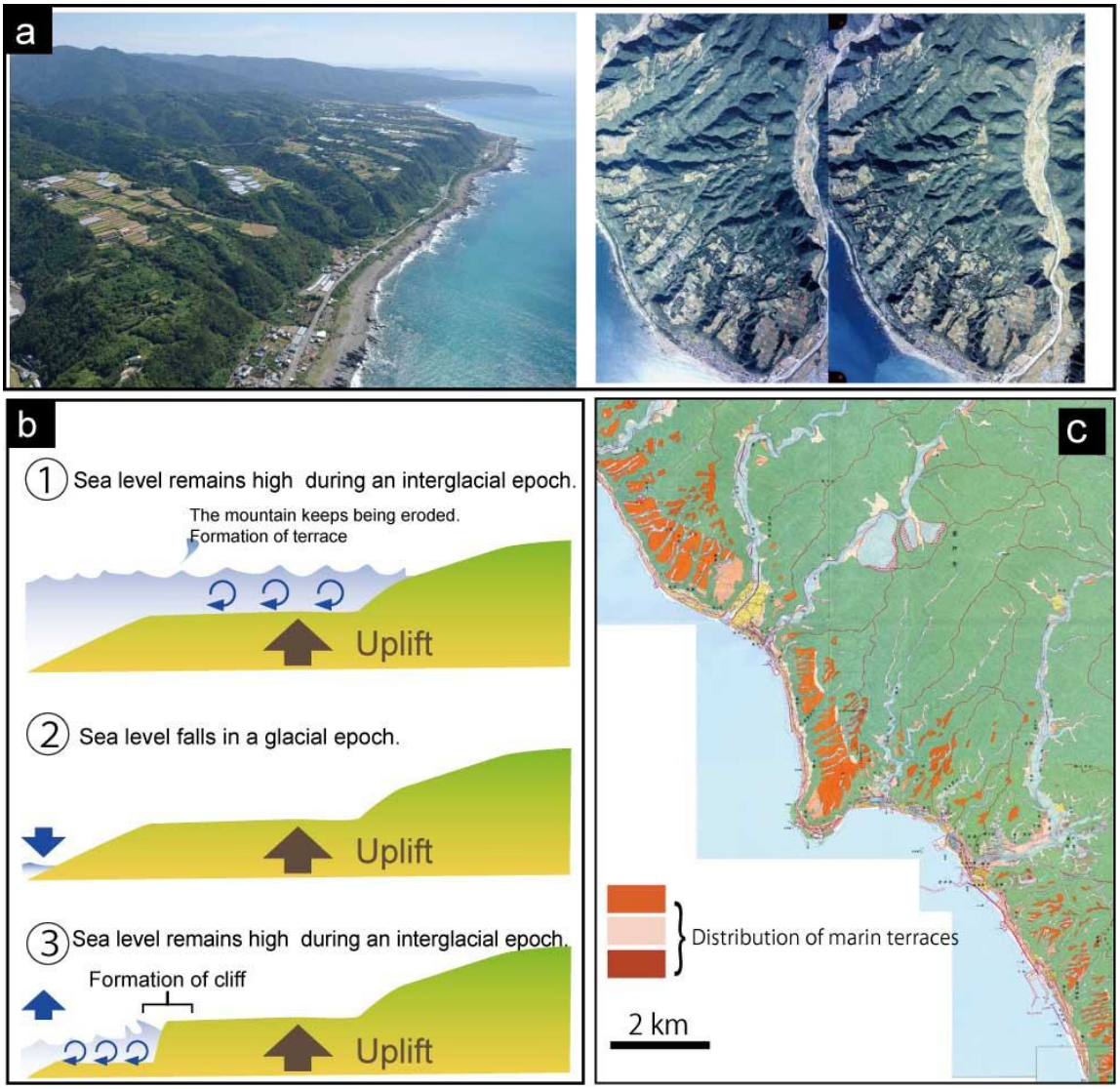

Figure B-10: a: Marine terraces (left) and their stereographic air photos (right)
b: Formation process of marine terrace c: Distribution of marine terraces

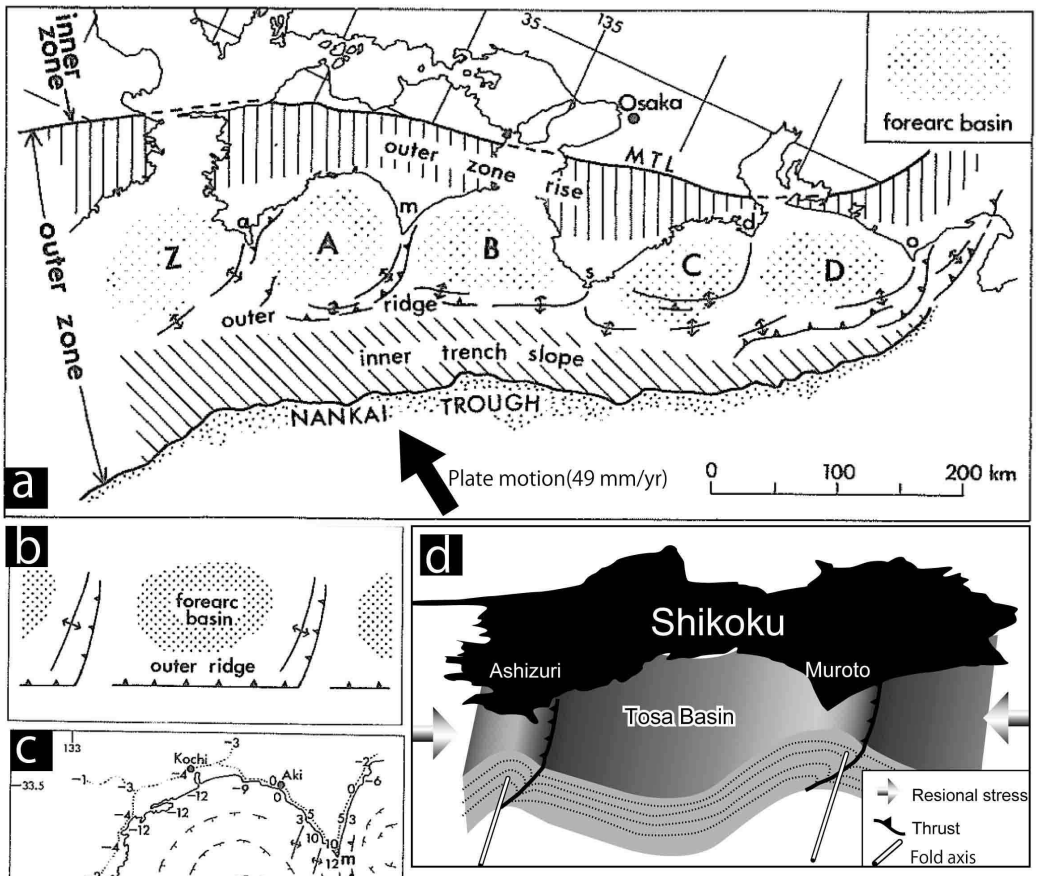

Figure B-11: Geological structure of outer zone (Awata and Sugiyama, 1989)

a: Geological structure of outer zone of southwest Japan. Major faults and anticlinal axis in freak basins, A, B, C, D and Z and the outer ridge are shown.

b: Comparison of vertical displacement due to the right-lateral low-angle reverse fault, with the structural unit along the Nankai Trough.

c: Geological structure in and around the Tosa Basin and the vertical displacements accompanied with the Nankaido Earthquake of 1946. Co-seismic displacements of the bench marks in 1935-1947 are shown in 10 centimeters. 1: dip and strike. 2: fault. 3: anticlinal axis.

d: Schematic model of topographic uplift in Muroto. The southward plunge of the NS fold axis resulted in the triangular shape of Cape Ashizuri and Cape Muroto.

On the west side of the Muroto Peninsula, marine terraces have developed along the coast (Figure B-10). The characteristic feature of these landforms is their formation process, i.e. the combination of sea level changes due to climatic variation and crustal movements caused by earthquakes. The terraces have been formed steadily since approximately 160,000 years ago.

Among the formations covering the Earth's surface, the deposition of the newest formation started at 2.588 Ma (i.e. Quaternary). The Quaternary Formation comprises the majority of the urban and farming areas with human dwelling. What characterizes the period is the episodic climatic variations including the glacial periods at an approximately 100,000 year interval, which develop the continental ice sheets, followed by an interglacial period lasting approximately 10,000 years after each glacial period. These climatic variations result in the repeated cycle of expansion and shrinkage of the continental ice sheets, which cause recurrent changes in the global sea level. The glacial and interglacial cycle has caused worldwide sea level changes by approximately 100 m.

The coseismic uplift has been continuing at an average speed of 1 to 2 m per 1,000 years (Sakai, 2003). This crustal movement and the inverted triangular shape of the Muroto Peninsula have a close relationship in relation to plate boundary process. Awata and Sugiyama (1989) and Okamura (1990) have described the geological structure around Shikoku Island as follows. The oblique subduction of the oceanic plate (Philippine Sea Plate) turned the frontal part of southwestern Japan to a compressional field (E to W) with repeated folds and thrust faults striking NS (Figure B-11). These folds and thrusts (active faults) have resulted in the steep fault scarp on the east coast of the Muroto Peninsula. The process caused Cape Ashizuri and Cape Muroto to be anticlinal and Tosa Bay synclinal. The southward plunge of the fold axis resulted in the gently curved shape of Tosa Bay and the inverted triangular shape of the Muroto Peninsula with its tip extending towards the south into the Pacific Ocean.

The process of marine terrace formation involved the following elements (Figure B-10b): 1) In the period of sea-level elevation, a platform is formed as waves keep eroding the same surface underneath. 2) In the period of sea-level fall, the shoreline regresses gradually, leaving the platform dried. The platform stays above water as a terrace. 3) A steep cliff is formed by erosion when the sea level rises again.

As described above, the magnificent landform of the Muroto Peninsula has been created by the coseismic uplifiting, accompanying the subduction of the Philippine Sea Plate under the Eurasian Plate along the Nankai Trough, and sea level changes in the Quaternary. In Muroto Geopark, a scenic road on the terrace slopes allows visitors to have a full view of the terrace plains. A lookout offers a panoramic view from a terrace top. These are the factors that help tourists and students visiting our geopark to understand the formation process of the land here. We believe that marine terraces in the Muroto Peninsula, introduced in textbooks for university or junior high and high school students, can be considered as the best example of marine terrace in Japan.
[Related geosites: C, G, P]

B-4-4. Tsunamis expected in the future

Figure B-12: Emerged landforms a: Sea cave b: Notch c: Pothole

Inevitably, a mega earthquake centered in the Nankai Trough off Cape Muroto is expected to occur in the near future. Around the Nankai Trough, large subduction-zone earthquakes of magnitude 8 have repeatedly occurred at an interval of 100 to 150 years. The most recent examples of such large earthquakes occurred in this ocean area are the 1944 Tonankai and 1946 Nankai Earthquakes. Approximately 60 years have already passed since those major events. Such being the circumstance, Muroto Geopark is the only geopark expecting a large-scale earthquake predicted in the near future. To establish a prediction model of such earthquakes, the emerged landforms of Cape Muroto and the records of the tide level observed at the Murotsu Port have played a crucial role. Additionally, drilling at seismogenic faults, as well as state-of-the-art research using ocean-bottom seismometers, has been conducted as a national project at the Nankai Trough. The project is expected to help understand the mechanism of the earthquakes and contribute to their prediction.

The earthquakes at the Nankai Trough occur when the two plates rupture (slip) as the Philippine Sea Plate (oceanic plate) subducts under the Eurasian Plate (continental plate) on which the Shikoku Island and Kii Peninsula are located. Sometimes the rupture involves active high-angle faults that branch out from the plate boundary surface into the continental plate. Such actions induce vertical crustal movements and characteristically cause massive tsunami.

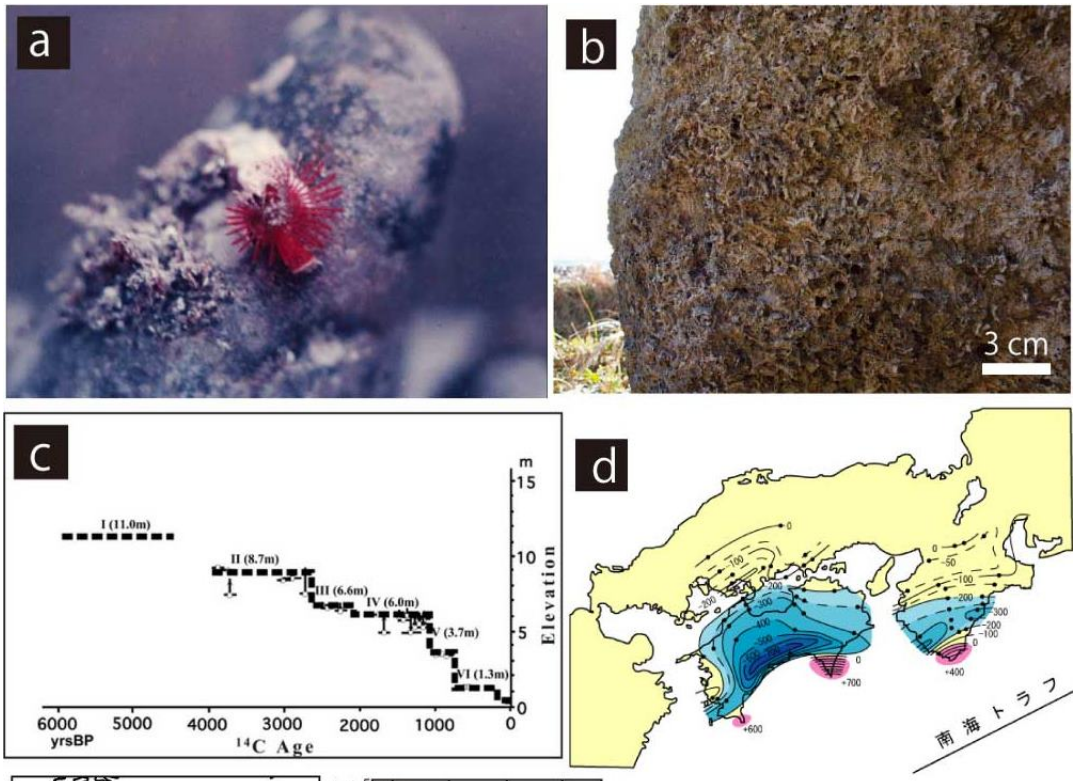

Figure B-13: a: Live Yakkokanzashi (*Pomatoleios kraussii)*
b: Fossilized tubes of *Pomatoleios kraussii*
c: Relative sea level changes around Cape Muroto since 6000 yrsBP, determined from raised coastal landforms and fossil sessile organisms. Roman numbers indicate stable period of sea level and figures in parentheses indicate its elevation. The symbol with error bars indicates the elevation and ^{14}C age of sample fossil. Upward arrows indicate upper-most height of fossil assemblage from which the sample was obtained.
d: The ground deformation at 1946 Showa Nankai Earthquake (mm) (modified after Fitch and Scholz, 1971)
e: Estimated hypocentral region for the Nankai Earthquake
f: The diagram indicates the relationship between the cumulative amount of uplift and recurrence interval of the past Nankai earthquakes. The long term prediction of the next Nankai Earthquake can be done by this diagram.

The landforms that emerged due to repeated earthquakes are well preserved on the Muroto peninsula. Examples of such landforms found throughout this area include sea caves, notches, sea cliffs, wave-cut benches and potholes (Figure B-12). The rocks emerged from the 1946 Nankai Earthquake can also be seen here. Fossilized calcareous remains of tube worms, Yakkokanzashi (*Pomatoleios kraussii*), that used to live in the intertidal zone, are found attached to the rock surface (Figure B-13a, b). From the height distribution and ^{14}C dating of the fossils, as well as the altitude of the marine terraces, it was found that relative sea-level fall occurred repeatedly due to the rapid coseismic upheaval accompanying major interplate earthquakes (Figure B-13c; Maemoku, 2001).

The latest studies at the Nankai Trough are roughly divided into two categories: the sampling within and around the seismogenic faults and observations with high precision. On the seafloor off Cape Muroto, drilling was conducted in 1990, 2000 and 2001. Integrated Ocean Drilling Program (IODP) was started in 2003 to conduct deep-sea drilling on the seafloor by a deep-earth exploration vessel, “Chikyu (the planet Earth) (Figure B-14).” Furthermore, the establishment of an “ocean floor network system” is under way in order to achieve a precise, real-time observation at the Nankai Trough. It is aimed to better understand the mechanism of Nankai Earthquakes which are expected to strike the Pacific side of western Japan in the future.
[Related geosites: J, M, U]

Figure B-14: Scientific drilling vessel, “Chikyu”
It is designed to operate at a depth of 2,500 m underwater and drill to a depth of 7,500 m.

B-4-5. The disaster and blessings from the sky and the ocean

The natural environment of Cape Muroto has been largely dictated by ocean and climate. The tip of Cape Muroto extends into the Pacific Ocean, being surrounded by the sea. On the west of the cape lies Tosa Bay, and on the east, Kii Channel and on the south, the Pacific Ocean. A warm ocean current flows off Cape Muroto, and the deep see water upwells at the east coast of the cape (Figure B-15).

Typhoons which originate in the Philippine Sea and approach Japan, sometimes hit Cape Muroto still retaining their peak intensity. Rain fronts and low pressures also pass by this area frequently. Due to stormy winds, often torrential rain falls almost diagonally and rough waves attack the coast. Such climatic factors cause extensive erosion of the land. Wave erosions also have played an important role in forming the coastal landscape, which manifested as marine terraces and emerged landforms.

The formation process of the land has a close relationship with the ocean current, including the upwelling of the deep sea water. The opening of the Japan Sea caused the warm current called the Kuroshio Current to flow northward in the East China Sea, then through the Tokara Channel into the Pacific Ocean, and finally, along the southern coast of Japan (Figure B-15c). The ecosystem on Cape Muroto and in the adjacent waters has been influenced by this warm current. The steep fault scarp formed on the east side of the cape by crustal movements has caused the upwelling of the deep sea water. Because of this landform, water harvesting is possible at the point approximately 3 km away from the coast and 300 m below the sea level (Figure B-15a).

Deep sea water refers to the sea water flowing in the deep ocean, and sometimes, such as in the mid-latitude region, such ‘downwelling’ water is found at a depth of 1000 m or more. The sea water is characterized by its purity, inorganic nutrient enrichment and stability at a low temperature. The purity results from the fact that, at this depth, no chemical pollution and/or plankton are present and the germ content of the water is one-thousandth of that of the sea surface water. Deep sea water is rich in inorganic nutrient compared to the surface water which is necessary for the growth of phytoplankton. The low-temperature stability means that the water temperature and the ingredients are stable throughout the year. Deep sea water travels from the ocean off Greenland through the Atlantic Ocean, the Antarctic Ocean, the South Pacific Ocean and to the northeastern Pacific Ocean, with a travel time of over 2000 years to finally upwells towards the sea surface.
[Related geosites: O, P, V]

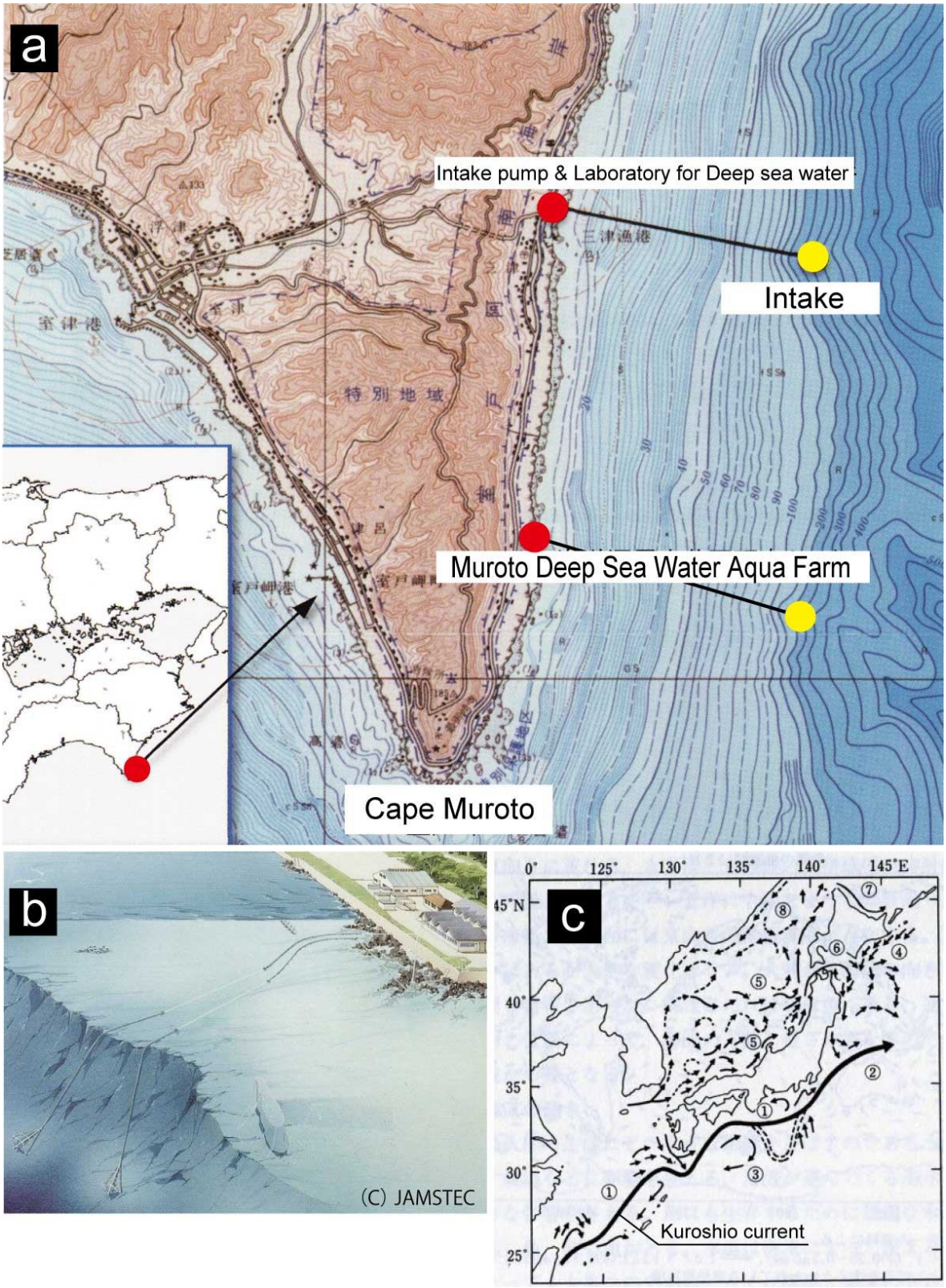

Figure B-15: a: Deep sea water intake points b: Water intake system
c: Ocean currents near Japan (Chronological Scientific Table, 2010)

C. GEOCONSERVATION

C-1. Current or potential pressure on the proposed Geopark

The geoheritage in Muroto is under ongoing changes due to coseismic crustal movements and strong wave and wind caused by typhoons. The stressors on the geoconservation efforts are man-induced damage or pollution. Details of such stressors are described below.

[Litter problem]

The problem includes littering by tourists and anglers as well as the litter washed ashore by ocean currents. In addition to the litter with Japanese labeling, much has labeling in Chinese, Korean, Vietnamese, English and French. To cope with the problem, we intend to further encourage the periodic patrols (three times a month) and beach cleanups throughout the year. Also, we plan to add 'No litter' message to map boards in the proposed geopark area to promote a litter-free environment. Another plan is to show the photo of the ocean litter on our official website to inform the world about this problem and consequently, raise awareness.

[Sampling]

Another example of a man-induced stressor is the reluctance of researchers to follow proper application procedures in getting permission from the landowner (mainly the local government) for obtaining samples. Researchers are expected to take extra care with regard to the method and location of sampling so as not to negatively affect the geoconservation efforts. We plan to ask researchers to comply with the law by asking various academic societies for assistance. Also, on our official website, we plan to provide guidelines including the permission criteria and application procedures for geologic sampling within the geopark. Furthermore, we plan to specify the method and areas permitted for the sampling in order to sustainably promote research activities in this area.

C-2. Current status in terms of protection of geological sites within the proposed Geopark

The geological heritage within the proposed geopark is protected by the Natural Parks Law (1957 Ministry of the Environment), the Act on Protection of Cultural Properties (1950 Agency for Cultural Affairs), the Ordinance to Protect Cultural Properties by Muroto City and the Basic Environmental Ordinance by Muroto City. In particular, development is strictly regulated in the coastal areas which belong to the Muroto-Anan Kaigan Quasi National Park (designated in 1964). In addition, the Basic Environmental Plan by Muroto City sets the policies of environmental protection through collaborative efforts of the government and the private sector.

In accordance with the above mentioned laws and regulations, periodic patrols and beach cleanup have been conducted within the Muroto Geopark. We plan to make further efforts to raise awareness towards geoconservation through pamphlets, signboards and websites.

C-3. Data on the management and maintenance of these sites

As mentioned above, the development of the area comprising geological heritage is restricted by laws and regulations. Efforts for a litter-free environment have been made through the cooperation of the government and community residents. Muroto City has conducted periodic patrols three times a month to cope with the litter problem. Beach cleanups have been held frequently and the cumulative number of community participants has reached more than 5,000 annually. (Figure C-1).

Table C-1: Periodic Patrols and Beach Cleanups

(Days)

	Periodic patrol	Beach cleanup	Total
Fiscal 2008	36	32	68
2009	36	38	74
2010*	36	32	68
Total	108	102	210

* (As of October, 2010)

Figure C-1: Cleanups a: Separating garbage b: Mowing grass c: Illegally dumped garbage

C-4. Listing and description of non-geological sites (Biological, cultural and industrial diversity)

The topography and geology, which have formed over a long time, strongly affect the lives of the people living in a given area. The topography influences the local climate and weather, and consequently, our living environment and the success of agriculture and fishery. Topographical diversity provides us with the land for residential or industrial use but at the same time, restricts usage of land.

As mentioned in section B, there are diverse ecosystems in Muroto influenced by the local topography and geology. The community's culture has matured as people have developed a variety of industries by utilizing the ecosystem and the environment. The efforts to minimize the damage of natural disasters and to take advantage of the local landform have been consolidated into the wisdom passed down for generations.

We present the list of geosites in Muroto Geopark as below. By visiting combinations of these geosites, the relationship between the earth and its people can be explained. The diversity in the topography and geology is described in C-4-1 to C-4-3. Industrial, cultural and historical diversities are also mentioned in the sections. Related 'points of interest' in the geopark are indicated by alphabets at the end of each section.

Table C-2: List of non-geological sites

Geosites	Description
C. Hazeyama-Nishiyama plateau	Farming on the plateau of the marine terraces. Crops such as loquats are being grown on the marine terrace slope.
D. Kiragawa town with traditional architectures	Historical townscape on the marine terraces formed by coseismic uplifts. Traditional houses here have ingenious structure to cope with typhoons and earthquakes.
E. Kiramesse Muroto (*See organizational chart for details)	"Geopark Gallery" was newly opened in the Whale Museum which exhibits information on the history of whaling as well as the relationship between ocean floor topography and whales.

G. Sakiyama plateau	Farming on the plateau of the marine terraces. Crops such as loquats are being grown on the marine terrace slope.
H. Narasni-Moto beach	This beach is a widely known sea turtle spawning site. Students at Moto elementary school have been helping with returning hatched sea turtles to the ocean.
I: Whaling Culture	Muroto once thrived by catching whales and tuna. One can see how tradition of grieving for hunted whales has raised awareness with regards to the importance of whales as part of the marine environment.
L: Toromu	A facility at Muroto-misaki fishing port with catering facilities, souvenir shop and a dolphin center run by an NPO. At the center, visitors can pet dolphins.
M: Cape Muroto	A place said to have been the training site of a prominent priest, Kukai, who is the founder of Shingon school of Buddhism. (Kukai can also be nicknamed as "the earliest mining geologist in Japan.")
N: The Pilgrimage road	The roads or trails that connect 88 pilgrimage temples in Shikoku Island, along which *o-henro* (pilgrims) walk in search of inner peace. Wild subtropical vegetation of significant value is observed alongside these tracks. Many parts of these run on uplifted wave-cut benches.
O: Deep Sea Water	Related facilities in this site include: research facility, health promotion and accommodation facilities, factories and a museum with information on the harvesting process of deep sea water.
S: Sakihama town	Folk performances designated as national and prefectural Intangible Folk Cultural Assets are popular in this town. Fertile soil brought from upstream area enables productive agriculture.
T: Mt. Dannotani	Along the trail leading up to a hilltop (Jizotoge on Noneyama street), large wild cedar trees are found. Some trunks of them reach up to a 13 m in girth.

C-4-1. Geodiversity and biodiversity

[Vegetation influenced by warm ocean current]

Due to the influence of the warm current, some subtropical vegetation is found in Muroto including that of the temperate zone. Around Cape Muroto, evergreen broad-leaved trees including *Akou* (*Ficus superba), Tabunoki (Machilus thunbergii)*, *Ubamegashi* (*Quercus phillyraeoides)* feature predominantly, as well as tropical plants such as *Tamashida* (*nephrolepis cordifolia)*, *Kuwazuimo (Alocasia odora)* and Ryuuzetsuran (*Agave americana*). *Shiogiku* (*Chrysanthemum shiwogiku*) communities are found in the rocky areas near the seashore. A distinguishing feature of the vegetation near the southern tip of the cape is due to the influence of the characteristically strong winds. Being hampered by the wind, plants grow into wind-beaten scrub or grow towards the downwind side only (Figure C-2). The vegetation in this area is designated as a protected species ("Cape Muroto Subtropical Forest and Coastal Vegetation") by the national government.

At Hotsumisakiji Temple (in Cape Muroto) and Kongo choji temple (on the Sakiyama Plateau) on top of the marine terraces, *Sudajii* (*Castanopsis sieboldii*) are dominantly found, along with *Bakuchinoki* (*Prunus zippeliana*), *Baribarinoki* (*Litsea acuminata*), *Nagi* (*Podocarpus nagi*), *Taiminntachibana* (*Myrsine seguinii)* and *yakkoso* (*Mitrastema yamamotoi*, parasite of *sudajii*).
[Related geosites: C, G, M, N]

Figure C-2: Vegetation a: Red arrows indicate the direction of strong wind. b: A parasite plant, Yakkoso (*Mitrastema yamamotoi)* that grows in subtropical regions. c: *Shiogiku* (*Chrysanthemum shiwogiku*) distributed in limited area in the southwestern Japan (national protected species)

[Natural forest in the site of coseismic landslide]

Mt. Dannotani, a geosite featuring a large-scale coseismic landslide that occurred in the past, is now covered by a wild cedar forest and many large trees with approximately 13 meters circumference (Figure C-3). In this site, repeated landslides caused by typhoons and earthquakes have formed a steep terrain. This resulted in many of the cedar trees growing with a deformed shape. The deformed cedars were not lumbered and have grown to be huge trees over 300 years old. This bountiful forest area produces rich soil underneath.

[Related geosite: T]

Figure C-3: Wild cedar tree

[Bountiful ecosystem nurtured by deep sea water]

In the ocean on the east side of Cape Muroto, the nutrient-rich deep sea water helps promote seaweed (*Gelidium crinale*) growth and consequently that of abalones (*Sulculus diversicolor supertexta*) which feed on the seaweed. On the west coast, sand beaches offer sea turtle spawning sites (Figure C-4). Local elementary school students have been helping with sea turtle conservation efforts.

The deep sea water also contributes to the bountiful ecosystem in the adjacent waters off Cape Muroto, which includes marine mammals such as whales and dolphins. Distribution of different whale species depends on the depth of the ocean; sperm whales live in the deep sea on the east of the cape, and right whales in the relatively shallow sea on the west (Tosa Bay side).

At the Muroto Dolphin Center, environmental education is provided through interactions with dolphins. Also a dolphin therapy program is available for children with pervasive developmental disorder.

[Related geosites: H, I, L, O]

Figure C-4: Various sea creatures a: Abalones (*Sulculus diversicolor supertexta)* b: Tale of a whale c: loggerhead sea turtle (*Caretta caretta)*

C-4-2. Geodiversity and industrial diversity

[Deep sea water and fisheries]

Deep sea water is rich in mineral nutrients that are necessary for the growth of phytoplankton (plant plankton). Thus, being blessed by the upwelling deep sea water, the east coast off the Cape Muroto provides an excellent fishing location. Local fishermen fish in these areas using fixed-net fishing method. Off Cape Muroto, there is a spot in which the ocean bottom is elevated (due to a subducted seamount), where valuable fish such as alfonsino are abundant (Figure C-5c).

[Related geosites: M, O]

Figure C-5: Fisheries a: fixed-net and ocean bottom topography b: Catching fish with fixed-net c: Fishing alfonsino

[Agriculture taking advantage of the terrain features]

On the marine terraces, crops such as sweet potatoes, eggplants and daikon radishes are commonly grown, taking advantage of ample drainage. Loquats are grown on the slopes, being blessed with abundant sunshine (Figure C-6). The rice fields in the flatland downstream of the wild cedar forests (see C4-1) are very fertile because of the soil and water brought down from this bountiful forest area.

[Related geosites: C, G, S]

Figure C-6a, b, c : Farming on marine terraces (Loquat)

[Ecology-friendly fuel]

The evergreen *ubamegashi* and oak trees that grow on the steep coastal terrain are used for the production of high-quality white charcoal called "*Tosa*[6]*Binchotan.*(Figure C-7)" Because of its strong heating properties, the *Binchotan* charcoal is still considered as ideal fuel in certain food industries. Currently, the movements to reduce CO_2 emissions to prevent global warming are drawing increased attention to this "ecology-friendly" energy source.

[Related geosites: D, S]

Figure C-7: Tosa binchotan charcoal a: Ubamegashi trees b: Charcoal in kiln c: Final product

[6]Tosa:Old name for the Kochi prefecture.

[Gift from deep sea]

The deep sea water upwelling on the east side of Cape Muroto is a gift from deep sea. Research and development on this water have advanced, as well as its many industrial applications. It is desalinated to be consumed as drinking water, and extracted minerals are used for various cosmetics and food products (Figure C-8). Muroto deep sea water is one of the domestically best-known mineral waters and marketed throughout Japan. Due to its favorable properties, it has been used for farming certain varieties of seaweed and shellfish, growing vegetables or for heated pool.

[Related geosites: C, G, L, O]

Figure C-8: Deep sea water products

C-4-3. Geodiversity and Cultural / historical diversities

[Living in symbiosis with nature: traditional houses]

Kiragawa town thrived as a distribution center for high-quality charcoal in Edo period (1603-1868). Traditional architecture such as main house, storage and stone walls are the historical legacy of this once-prosperous rural town (Figure C-9). When most of the houses were built in this town in early Meiji period (1868-1912), the primary industry of the community was the production of white charcoal, *Tosa Binchotan*. This valuable charcoal with strong heating properties sold well in metropolitan areas of that time including Osaka and Kyoto where demand was high. The profit from the sales allowed for the construction of houses with traditional ingenuity.

Since Muroto is often hit by typhoons, the ingenuity and wisdom of previous generations have been applied to architectural structures in this area to cope with strong wind and rain. The ingenuity is also observed in the way houses are built on the terraced landform in town which resulted from coseismic upheaval. Houses are built short on the upper terrace and tall on the lower terrace to make them approximately the same height. The aim is to avoid the storm wind hitting the taller buildings harder.

[Related geosite: D]

Figure C-9: Kiragawa townscape a: Storehouses built on a terraced part of town
b: Stone walls called “Ishiguro” c: A guided tour

[Whaling Culture]

Since ancient times, the Japanese have passed down the tradition of expressing gratitude for the food and animals that they eat, because those are what sustain their lives. In Muroto, blessed by the bountiful ocean, the community was once prospered by ancient and modern whale hunting, which is no longer continued today. However, the tradition of grieving for hunted whales still remains reflected in cultural ceremonies. For example, whale-boat (paddling boat) racing has been held annually. Mortuary tablets[7] and gravestone for hunted whales are found in the community, and a whaling folk song has been passed down for generations.

[Related geosites: E, I]

[7] Mortuary tablets: A tablet with ancestors’ posthumous name on used by Buddhists.

[Pilgrimage in Shikoku Island]

There is a unique pilgrimage culture in Shikoku Island, where pilgrims visit 88 temples spread over this island. The temples are said to have been built about 1,200 years ago in association with Kukai, in order to save people from misfortune and lead them to inner peace.

Places associated with Kukai are concentrated on Cape Muroto, including the sea caves and ponds that are related to his ascetic training. These emerged landforms resulted from large earthquakes. Some see Kukai as the earliest mining geologist in Japan because he is said to have prospected mercury ore deposits. There might have been a geology-related reason that he chose Cape Muroto for his training site.

The location of two pilgrimage temples in Muroto, Hotsumisakiji and Kongo choji temples, was chosen for the reason related to the geological features of the area. The 88 temples are located around the Shikoku Island along the coastline, but none is found where the terrain is too harsh. The “no-temple” zone is longest between Yakuoji temple (Minami town, Tokushima prefecture, 80 km northeast of Cape Muroto) and Hotsumisakiji temple (Cape Muroto). This coastal area with very little beach and flatland is scarcely inhabited and not suitable for building temples. Meanwhile, marine terraces have developed on the west coast of Cape Muroto, offering plenty of land to build houses on. For this reason, temples including Hotsumisakiji and Kongo choji temples are located on marine terraces.

[Related geosites: G, M, N]

Figure C-10: a: Kongochoji Temple b: Hotsumisaki ji Temple c: O-henro (pilgrim)

D. ECONOMIC ACTIVITY AND BUSINESS PLAN

D-1. Economic activity in the proposed Geopark

D-1-1. Agriculture and forestry

In Muroto, residents are active in agriculture aided by sunny winter with little frost or snow. Various crops are raised on farms on terrace plains. Popular greenhouse crops there include eggplants and cucumbers, while watermelons, sweet potatoes are grown outdoors. Loquats and ponkan oranges are grown on the slopes.

As for forestry, the city has been a major producer of charcoal, “Tosa Binchotan” made from evergreen *ubamegashi* and oak trees widely distributed on the coastal steep topography. The movements to reduce CO_2 emission to prevent global warming are drawing increased attention to this “traditional yet modern energy source.” The community once enjoyed prosperity as the key producer of the charcoal. The production has declined as gas and electricity became more popular energy sources. Yet, the charcoal from this area is still considered as ideal fuel in certain food industries.

D-1-2. Fisheries

The fishing industry, mainly based on fixed-net fishing, has been a key industry with the yearly sales of more than 8.2 billion yen (as of 2008). Traditional fixed-net fishing called *Ohshikiami* is still common in this area (Figure D-1). Also, five artificial floating fish reefs called “*Kuroshio Bokujo* (black current farm)” are located off Cape Muroto and contribute to the activities of many people engaged in fishing.

Deep-sea tuna fishing has not been very promising, but the local catch of alfonsino is one of the best in Japan, and there are plans to brand Muroto alfonsino in order to increase the sales.

Also, Deep sea water has been utilized for ocean farming. At the Takaoka branch of Kochi Prefecture Fishery Association, full-fledged production and marketing of green seaweed (*Ulva prolifera*) has started. In addition, it has been planned to start a production of seeds of abalone (*Sulculus diversicolor supertexta*) through a collaborative project of Muroto City and Kochi University.

Figure D-1: Fisheries a: Artificial floating fish reef called *Kuroshio Bokujo* (“Kuroshio current” farm*)*
b: Fish on the fish market c: Farming green seaweed (*Ulva prolifera*)

D-1-3. Deep sea water industry

Research and development on deep sea water have advanced as well as the prospects of water harvesting facilities. These advances helped create a deep-sea water industry, which is focused on the production of drinks and food products. The new industry has grown to achieve yearly sales of 13 billion yen at present.

In April 2000, Muroto Deep Sea Water Aqua Farm was founded for the further study and commercialization of deep sea water (Figure D-2a). Since then, the facility has been providing industrial firms with harvested deep sea water for profit. Up to September 2010, over 120 business proejcts in and outside of the prefecture have developed more than 600 deep-sea-water related products.

In July 2006, the Muroto Deep Sea Water Experience Center opened under the name of “Bade Haus Muroto” (The name was changed to “Searest Muroto” in July 2009) (Figure D-2b).The facility has a heated pool and an open-air spa, both using 100 % deep sea water. It has been contributing to the promotion of community health and an increase of non-resident population in this city.

Recent research and development has focused on applying the purity and nutrient richness of Muroto’s deep sea water to new fields, such as the medical field.

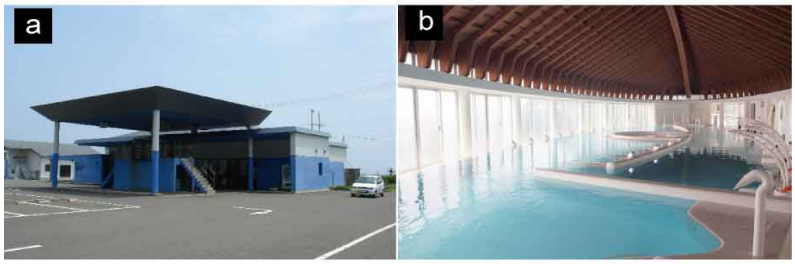

Figure D-2 a: Muroto Deep Sea Water Aqua Farm b: Searest Muroto

D-1-4. Tourism

Muroto Geopark’s popular attractions include the scenic coastline around Cape Muroto, the 88 temples pilgrimage in Shikoku Island associated with Kukai, the Kiragawa townscape, deep sea water facilities and marine recreational activities including whale watching and dolphin petting.

Also Cape Muroto has been included in various scenic selections such as New Eight Views of Japan, 100 travel destinations in Japan, 100 Japanese beaches, 100 Japanese sounds to hand down to future generations, 100 sites to visit for *haiku*[8]poem composition. With a recent designation as a “Lover’s Sanctuary[9],” which is a new tourist attraction, Cape Muroto has become a main tourist destination of the eastern district of Kochi prefecture.

Although the number of tourists is increasing yearly, most accommodation facilities are not capable of receiving large groups of tourists. The situation needs to be improved to promote ‘long-stay’ tourism.

D-2. Existing and planned facilities for the proposed Geopark

D-2-1. Existing facilities

Table D-1: Facilities related to education and research

No.	Facilities	Note
1	National Muroto Youth Outdoor Learning Center	Nature experience based learning center
2	Kochi Prefectural Deep Seawater Laboratory	Deep sea water harvest and research facility
3	Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET/ JAMSTEC), Muroto Land Station	A hub facility for the observation of tsunamis/earthquakes, established by JAMSTEC
4	Muroto Geophysical Observatory	Established by Earthquake Research Institute, The University of Tokyo

8.***Haiku*:** Japanese traditional short poem consisting of three lines and 17 syllables.

9.**Lover’s Sanctuary:** A nationwide project by an NPO aimed to promote tourism and counteract the falling birth rate. Scenic points known as popular “marriage proposal sites” are designated as “lover’s sanctuary” by some celebrities.

Table D-2: Facilities related to geotourism

No.	Facilities	Note
1	Muroto Geopark Information Center	Tourist information Arrangement of guided tours (Two full-time staff members)
2	Muroto Geopark Gallery	Located on 2F of Kiramesse Whale Museum(Two full-time staff members)
3	Muroto City Tourism Association	Tourist information Souvenir shop
4	Kiragawa Machinami-kan	Kiragawa town general information center (One full-time staff member)
5	Kiragawa townscape	The only “Preservation District for Groups of Traditional Buildings” in Kochi prefecture. (Designated in Oct. 1997 by national government)
6	Kiramesse Muroto (Shokuyuu Isanogou)	A restaurant in a roadside rest area
7	Kiramesse Muroto (Rakuichi Market	Farmers’ market in a roadside rest area
8	Kiramesse Muroto (Whale Museum)	Resource center with information on whaling history Souvenir shop
9	Muroto Deep Sea Water Aqua Farm	Deep sea water harvesting/supplying facility
10	Searest Muroto	Health promotion facility using deep sea water
11	Kochi Prefecture Fisheries Cooperative Association, Takaoka Branch, Green Seaweed Production Factory	Facility for farming green seaweed (*Ulva prolifera*) in deep sea water
12	Umi-no-ekiToromu	A facility at Muroto-misaki fishing port with catering facilities, souvenir shop and a dolphin petting center run by an NPO.
13	Muroto Dolphin Center	Dolphin petting center
14	Cape Muroto Lighthouse	It has the brightest and most far-reaching beam (No. 1 in Japan). A “Heritage of Industrial Modernization” (designated February 2009 by national government)
15	Hotsumisakiji Temple	Temple #24 of 88 pilgrimage temples on Shikoku Island
16	Shinshouji Temple	Temple #25 of 88 pilgrimage temples on Shikoku Island
17	Kongochoji Temple	Temple #26 of 88 pilgrimage temples on Shikoku Island
18	Accommodation Facilities	Total number of facilities: 28 Accommodation capacity: a maximum of 1,280 tourists / night

D-2-2. Planned facilities

Table D-3: Facilities related to disaster prevention

No.	Facilities	Note
1	Disaster Prevention Park	Emergency storage, water tank, and rescue heliport are planned
2	Digital wireless disaster prevention communication system operated by Muroto city	62 outdoor broadcasting devices to be installed

Table D-4: Facilities related to geotourism

No.	Facilities	Note
1	Kiragawa Town General Tourism Information	Relocation of existing facility is planned
2	Muroto Geopark Museum	The concept is under discussion.

D-3. Analysis of geotourism potential of the proposed Geopark

D-3-1. Strengths

- Landforms caused by dynamic movements of the earth including plate motions, coseismic upheaval and sea level changes can be closely observed. This is the only geopark where visitors can learn firsthand the relationship between the ocean and the land.

-Though snow in winter causes inconvenience at many other Japanese geoparks, the Muroto Geopark is a good observation destination all year round due to favorable climatic conditions.

-In addition to the geoheritage, wide variety of community resources are available including:

- subtropical vegetation,
- coastal plant community
-Buddhist pilgrimage,
- traditional whale hunting culture,
-traditional townscape of Kiragawa,
- wood charcoal (Tosa Binchotan),
-deep sea water
- abundant food
- marine recreational attractions, and
- folk performances reflecting the uniqueness of each community

- Opening of the Muroto Geopark Information Center has improved the arrangement of guided tours.

D-3-2. Weaknesses

- The size and quality of the hub facilities are not sufficient.
- The number of tour guides needs to be increased. Currently most tour guides can give tour at only one geosite.
- Transport infrastructure is inadequate
- Few accommodation facilities can accommodate large groups of tourists

D-3-3. Future vision

Owing to the temperate climate of Muroto Geopark, visitors are offered a year-round opportunity to view the unique geoheritage of the area, which gives an insight into the dynamic geological forces of the earth. The geodiversity is closely related to the biological, cultural and industrial varieties, which allow visitors to learn firsthand how the earth and people are related. With these strengths, we aim to achieve the following. In order to encourage tourists to stay in Muroto as long as possible, these three areas will be focused: 1) promote experience-based tourism, 2) encourage tourists to visit many places within the city and 3) display a sense of hospitality in all services. Another plan of ours is to develop commercial products with an emphasis on the concept that they are “the gift of the earth,” in order to improve the production activities of businesses.

To overcome the weaknesses, our efforts will focus on the following three areas: 1) discuss and plan the location, administration and exhibits of a prospective hub facility, 2) provide tour guides with training to prepare them for tours at several geosites, and 3) promote collaboration between the facilities to accommodate large groups of tourists.

D-4. Overview and policies for the sustainable development

We aim to conduct our geopark-related activities based on the concept of "sustainable development," by utilizing the natural environment to improve our quality of life "without compromising the ability of future generations to meet their own needs." Below are our policies for community development in a sustainable manner by balancing the conservation and utilization of geoheritage in the Muroto Geopark.

D-4-1. Geotourism and economy

We aim to establish a geopark, as a new booster for tourism promotion, in which visitors can learn about the formation of the earth and the synergy between man and nature by visiting various points of interest. Also, we will encourage business concerns to actively merchandise geopark-related products in order to revitalize the local economy.

[Tourism for enjoyable learning and mutual interaction]

- Promote experience-based tourism that satisfies the tourists' five senses (sight, hearing, smell, taste and touch) (Figure D-3).The content of the experience-based tour programs will be discussed by the Muroto Geopark Promotion Committee and the tourism facilities involved.

Figure D-3: Experience-based tour programs a: Farming (Picking tea leaves) b: Fixing a local cuisine c: Kayaking

- Encourage visitors to stay longer, visiting as many points of interests as possible within the geopark.We will suggest tour routes tailored to the interests and needs of the visitors so that they can easily understand the geopark. Such model tour courses are to be available also on signboards, pamphlets and websites. Arrangements will be made to have geopark information available at various catering, tourism and accommodation facilities, and to have their staff talk about attractions of the geopark. We will discuss the location, administration and exhibits with the aim of opening an attractive new hub facility.

- Encourage the whole community to display a sense of "hospitality" in all services provided in the tourism industry. In Shikoku, there has been an old tradition of supporting pilgrims by offering as much help as possible, and this sense of hospitality is still shared by many community residents. However, the attitude has not necessarily been applied to the professional services offered at tourism facilities in this area. Thus, we will encourage service providers to learn from the tourists' feedback and the services provided in other sightseeing areas / geoparks, and implement best practice in the service provided at this geopark.

In order to realize these policies, we plan to familiarize the community residents with the overall concept, and provide basic information about the Muroto Geopark. We also intend to train tour guides on the skill of emphatically relating the attractions of geosites with the geopark concept. Guide training officially started late in fiscal year 2008. Since then, training course consisting of 6 sessions have been given every year. For further progress, on-site practice meetings are held every Saturday morning for the trainees who completed the course and are certified.

Table D-5: Guided Tours

Organization	Number of registered tour guides	Number of tourists guided		
		Fiscal 2008	2009	2010***
Muroto City Tourism Association	*20	**81	563	531
Kiragawa Town General Information Center	8	5,921	3,840	1,209

* Three of the registered guides can give tours in English.
**The figure from January to March, 2009. (Japanese fiscal year is from April 1st to March 31st)
*** As of October, 2010.

Figure D-4: Tour guide training course a: Trainees in the class b: Guided tour c: Registered volunteer tour guides

[Product development with the sales concept of "geological gifts from nature in the geopark"]

We aim to develop products that allow recipients to appreciate the blessing of nature within the geopark. The purpose is to familiarize the general public with the significance of our geopark and encourage the production efforts of various businesses.

For that purpose, we plan to add value to conventional commercial products from Muroto by mentioning their relationship with the geopark (e.g. by adding geopark logo) on the packages and advertisement media. The effort will also include the development of new geopark-related products such as food, clothes and souvenirs (Figure D-5).


Figure D-5: "Geo curry" A dish made with the ingredients that are a "gift from nature in the geopark." The menu reads: " Vegetable curry made with seasonal vegetables, the gift from nature. They were grown on marine terraces in the Muroto Geopark which is blessed with internationally-valuable geoheritage (in Japanese)."

D-4-2. Geoeducation

Our aims are to develop children's capabilities for their brighter future, and also to raise awareness among community members towards disaster prevention. Through geopark activities, various people with various values, including teachers, community members, researchers and foreign people, will be involved in the field of education. Such diversity should enrich and diversify children's learning experiences. Additionally, the correct knowledge on the process and mechanism of natural disasters, obtained through disaster prevention education, should allow community members to minimize the damage of future disasters. Muroto Geopark serves community residents, especially children who are the bearers of the future. It places a strong emphasis on education. In the following section, we discuss geology education for children and disaster prevention education for community residents with specific examples.

[Education to foster children's potential]

We aim to educate children to be:

- researchers or educators not only in earth science but also in natural sciences,
- good communicators, and
- contributors to the sustainable development of the local economy.

Children can obtain important information from many people involved in geopark activities. This will assist their decision-making in general life as well as in vocational decisions. Education through the geopark has great potential and helps children develop the ability to investigate things from different perspectives, inquire into the cause of things and draw conclusions. Moreover, it is expected that the community would interact with tourists and researchers from all over the world. We expect that the community will achieve economic development through these experiences and with the abilities developed through them.

Among the recent activities by Muroto Geopark related to geology education, the most influential was The 11th Children's Summer School on Earthquakes and Volcanoes (hereafter “Summer School”) held in Muroto in August 2010. The Summer School is an outdoor learning program cooperatively held by the Seismological Society of Japan, the Volcanological Society of Japan and related local groups. Children participate in experiments and quizzes, both in- and outdoor, for two days, and make a presentation at the end on their discoveries and ideas gained from the experiences. This year, the event was held in Muroto Geopark, and participant children became “Muroto Geopark Kid Advisors” (hereafter “Kid Advisors”) who are expected to make a unique contribution to the geopark promotion activities.

After the Summer School, request from schools for guest lectures on the Geopark have increased, which has encouraged school teachers to start their own creative efforts in geopark-related education. Examples range from activities to reflect upon the children’s outdoor learning experiences, to the creation of artistic works such as objet, painting, drama, haiku (Japanese short poem), and music (Figure D-6). We intend to continue such activities from a children’s point of view.

Figure D-6: **Geoeducation a: Children guessing the epicenters of earthquakes at the lookout b: Tsunami experiment c: Children observing the difference in color and weight of the stones**

[Disaster prevention education to enhance the networking among community members]
The awareness of disaster prevention is very high among community residents. Lectures by scientists are held frequently to educate the public on the mechanism and damage of earthquakes in an easy-to-understand manner. Also, signage is located throughout the city with necessary information such as altitude and the location of evacuation shelters (Figure D-7a, b, d, e). The underlying reason is that the probability of a large-scale earthquake occurring within the next 30 years is about 60 %. If a Nankai Earthquake occurs, over 50% of the predicted death toll in Muroto City is expected to be caused by tsunami (The 2nd Basic Research for Disaster Prevention -- Earthquake 2006, Kochi prefecture).

In Muroto City, 84 autonomous disaster prevention organizations exist (as of March 2010) to minimize the damage caused by fires, earthquakes, tsunamis and typhoons. Each of them has been conducting training and evacuation drills independently, while an evacuation drill involving the entire city has been held annually (Figure D-7c). We understand the importance of community networking based on the correct knowledge on earthquakes. Based on this understanding, our efforts in disaster prevention education will continue in the future.

Figure D-7: Disaster prevention awareness a: Disaster prevention map b: Signage leading to tsunami evacuation area c: Disaster drill d: All gas stations have signage showing the altitude. e: Signage showing expected inundation area (Along national road Route 55, outside of Muroto City)

D-4-3. Geoheritage

The coastal area in the Muroto Geopark has been designated as “Muroto Anan Kaigan Quasi National Park,” which restricts the sampling in certain areas within the park. However, in order to balance the geoconservation and development in the community, it is crucial for the scientists and the Muroto Geopark Promotion Committee to work cooperatively to ensure that research findings are reflected in geopark activities. We plan to continue to support scientists’ field work, conduct collaborative research, advertise our geoheritage as a potential research site, attend academic conferences and attract field trips.

For researchers’ field work, negotiation with the landowner is crucial. However, obtaining permission can often be complicated, or the application contact is not publicized, or the landowner’s whereabouts are not known, all of which can be obstacles to proper procedures. Thus, the Muroto Geopark Promotion Committee plans to aid in clarifying the application procedure, and encourage researchers, with the assistance of academic societies and universities, to take proper application procedures. The committee will provide permitted researchers with some identification (such as an armband) to wear when sampling in the field.
The universities and research institutes that are affiliated members of Muroto Geopark Promotion Committee are expected to be actively engaged in collaborative research with the geologist (Phd.)

who is a full-time staff of the said committee. Reporting the research findings is expected to make the geoheritage in the Muroto Geopark known to the public.

Academic conferences and field trips by many academic societies and research institutes have been held in Muroto, and these have significantly influenced this research field. At the International Conference on Accretionary Prisms held in Muroto in 1991, the geoheritage in Muroto impressed about 130 geologists from 10 different countries. The International Symposium and Field Workshop on Gondwana Evolution and Dispersal held in 2004[10] hosted a large-scale field trip with about 100 scientists attending from 20 countries.

Table D-6: Field Trips in 2010 (with over 20 participants)

Date	Host organization	Participants	Note
February 19	Hiroshima University Faculty of Science	40	Undergraduate sophomores and 3rd graders For educational purpose
May 17	IODP (Integrated Ocean Drilling Program)	34	Conference participants (Researchers and graduate students) For reporting research results
June 4	Kochi Core Center	20	Researchers and assisting staff For Geopark inspection
June 4	A Kyushu field trip group to observe Quaternary outcrops	33	Researchers, university students (graduate and undergraduate) For research and educational planning
August 25	Joint Meeting of Korean and Japanese Geological Societies	50	Conference participants For reporting research results and educational purpose
October 30	Kobe University Faculty of Science	25	University students For educational purpose

Muroto Geopark plans to establish a system in which landowners and community residents can benefit from the research findings obtained in the area. Also we plan to report the most up-to-date research findings to the world through the collaborative efforts by the Muroto Geopark Promotion Committee and researchers. Such findings will be reflected in geoeducation, symposiums, content of the exhibits at geopark hub facilities, guidebooks and signage. We also aim to exhibit research vessels and ocean floor core samples through joint efforts with Kochi University, JAMSTEC and the Kochi Core Center. Our hope is that these efforts will enhance mutual understanding between the researchers and the community, add to the value of our geoheritage and allow the community members to enjoy geopark activities.

D-5. Policies for, and examples of, community empowerment in Muroto Geopark

The most important factor for the sustainable development of the community is the residents' initiative in the geopark promotion. We hereby identify the three areas of emphasis with specific examples.

- Awareness raising among community members

  Efforts will be continued to encourage community involvement with geopark activities by frequently talking with people and explaining about our geopark at various local gatherings (Figure D-8). Recently, some residents have started voluntarily conducting events from their own ideas to support the geopark.

Figure D-8: Giving a talk at a community gathering

[10].The symposium was held by Kochi University.

- Cooperation among catering, tourism, and accommodation facilities

We aim to encourage the employees of said facilities to supply information to tourists on other facilities and geosites. Committed members of the association of local accommodation facilities are referring tourists to each other lately. One facility has even developed a morning-stroll program combined with yoga practice for their guests to try in a coastal geosite.

- Promotion of education

This is our area of emphasis. As mentioned in 4-2, request for geopark-related guest lectures has increased after the Summer School, which seems to have inspired school teachers to use geoeducation in their own creative manner. The Summer School was a fruitful learning experience not only for the children but also for the adults who were involved in this event, including the Muroto Geopark Promotion Committee members, local government employees, school staff and tour guides. This experience undoubtedly contributed to the promotion of geology education. We continue to value children's viewpoint in geopark activities, such as adopting the opinions and ideas of Kid Geopark Advisors. In addition, establishment of a local "earth science association" by local school teachers is being discussed in order to provide guest lectures and prepare teaching materials. A notable step is the introduction of "Geopark Course" into curriculum at Muroto High School starting school year 2011.[11] This is offered as a credited course, which is a very unique attempt in Japan.

We aim to place an emphasis on environmental education as well. For example, since 1960, students at Moto elementary school have been helping with returning newly hatched sea turtles to the ocean. Geopark-related knowledge will be integrated into such activities of environmental education.

Table D-7: Talks and visiting lectures in 2010 (as of October 2010)

Activity	Description	Frequency	Participants
Talks at community meetings	To familiarize members with geopark and raise awareness towards	30	About 1,500
Visiting lecture	At Muroto elementary school, Mitaka elementary school Higashi junior high school	3	60

D-6. Policies for, and examples of, public and stakeholder awareness in the proposed Geopark

In order to draw attention to geopark activities, we plan to actively continue our information distribution and awareness raising. Efforts will be made to familiarize not only the Muroto residents but also those living outside the city with the attractions and the value of geopark-related activities. Such efforts should encourage increased numbers of people to be interested in the geopark and voluntarily offer support. Supplying information throughout the community is expected to not only draw attention to but also improve Muroto Geopark itself. Active advertisement will attract public attention and simultaneously give more opportunities for mass media, tourists and travel agencies to provide feedback about the geopark. Our advertising efforts should always be followed by improvement efforts. Through this cycle of spreading information, receiving feedback and improving weaknesses, our geopark activities should progress with better outcomes.

Another important plan is to develop travel plans by collaborating with travel agencies. The Muroto Geopark Promotion Committee and travel agencies share a mutual interest in utilizing Muroto Geopark as a tourism resource. So far, a few "geotours" were conducted as well as the launch of tickets that

[11] Japanese school year is from 1st April to 31st March.

includes the cost of bus service and a guided tour at one geosite. We will continue to encourage travel agencies to plan geopark-themed tours.
Our achievements so far are as follows:

[Attracting public attention]

We have been active in sending press releases to the media and marketing the geopark to publishers. Also our official website is frequently updated, providing up-to-date information. A promotional DVD was produced and sent to the media both within and outside the prefecture, schools, government organizations, accommodation facilities and travel agencies.

Promotional activities also include that by "Muroto Geopark Goodwill Ambassadors[12]." Original events have also been conducted. Examples include an event related to "Geology Day[13]," a photo contest of geopark-themed photos, haiku meetings and a travelling exhibition of a professional photographer. Adding the geopark logo on the designated garbage bag of Muroto City[14] is another idea for advocating environmental protection.

[Attracting Stakeholders]

Muroto Geopark intends to increase the number of geopark-related products. We plan to encourage businesses to add the geopark logo to the labeling on their conventional products to add value. In the advertising efforts, it will be emphasized that the food products are made from nature's bounty in the geopark. New geopark-related products have been introduced lately, including T-shirts, polo shirts, caps, mobile phone straps, magnets," geo *bento*(boxed lunches)[15] and geo curry[16] (Figure D-9).

Figure D-9: Activities and products to raise interest:
a: Muroto Geopark Goodwill Ambassadors, "Superband" b: Geopark-themed T-shirts and polo shirts
c: Geopark-themed food, "Accretionary wedge cake"

[12].**Muroto Geopark Goodwill Ambassador**: A female duo, "Superband" was delegated this position in August 2010. One of the members is from Muroto City.

[13]. **Geology Day**: The day (May 10th) to commemorate the first completion of a regional geological mapping in 1876.

[14].**Designated garbage bag**: In most places in Japan, garbage must be brought to designated spots in town for collection in semi-transparent plastic bag designated by the local government. The aim is to enforce garbage separation.

15. **Geo bento:** Lunch packed in bento box. Food are made with local food ingredients and arranged to illustrate some geological features of Muroto Geopark, such as turbidite layers.

[16].**Geo curry:** Curry dish served at a local restaurant. Almost all vegetable ingredients are the crops grown on the marine terraces in The Muroto Geopark.

E. INTEREST AND ARGUMENTS FOR JOINING THE GGN

The concept of the Muroto Geopark, “Where the ocean and the land meet – the forefront for the birth of new habitable land” summarizes the phenomena occurring at subduction plate boundaries. As has been mentioned in this application, our geopark possesses valuable geological heritage that fully embodies this concept. The geodiversity of the area has created biological, cultural and industrial variations, which has allowed us to secure enough resources to establish a global-level geopark. These resources have been actively utilized for education, disaster prevention, research studies and geotourism activities. The utilization will continue, with the conservation efforts of such heritage, towards the sustainable development of the geopark.

Our application for the Global Geoparks Network (GGN) has three purposes.
The first purpose is to let the world know the geoscientific significance of Muroto’s geoheritage through the alliance with other GGN member geoparks. Many of those geoparks are located in the areas on stable continents (e.g. Europe or China). There are very few geoparks where visitors can learn about the characteristic geodiversity of a tectonically unstable zone. At Muroto Geopark, one can learn about the ongoing processes characteristically taking place in a subduction zone. Additionally, since it is a geopark expecting large earthquakes and tsunamis that are predicted to occur, the methods of prediction and protection using state-of-the-art scientific and technological advances can be witnessed here. With these geological features, the Muroto Geopark can contribute to the geodiversity that GGN possesses as a network. Moreover, it can show the world how the area formed by tectonic actions sustains our community.

The second purpose is, by joining the GGN, to strengthen the networking among our community members, considering the affiliation with the GGN as one step in our ongoing progress. We are aware of the need to re-evaluate community resources, encourage networking among members from various walks of life and cooperate by sharing information. Being accepted as a member of the global network is not the final goal of the Muroto Geopark Promotion Committee. Rather, we aim to increase the local people’s interest in the community, stimulate their curiosity and increase their sense of pride. We ambitiously hope to achieve the aims and vitalize the community by participating in the GGN and by subsequently conducting geopark promotional activities.

The third purpose is to make a positive influence on other areas with geoheritage. Many areas in the world are suffering from depopulation and declining industry, even though they possess geological resources to establish a geopark. If Muroto City, with these issues, can conserve and utilize its geoheritage and achieve a sustainable development, it can encourage areas with similar problems elsewhere in the world.

With the purposes mentioned above, we hereby express our intention to join the Global Geoparks Network and make a contribution to its activities.

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