3. Mt. Fuji

Mt. Fuji with its superb height and volume, eminent snow capped peak, and symmetrical beauty of flank line has become a symbol of Japan. She has over twenty eruption records during historical time, and the latest eruption in 1707 was the most furious Plinian event with over 1300 million tons of air fall ash devastating some hundreds of square kilometres.

In 864 AD huge amounts of lava flowed out from the vents on the northern flank of Mt. Fuji, covering an area of 30km² which is now covered by dense wood and is called Aokigahara Wood-sea. This lava flow is almost unpassable because of the rough surface of the flow and sight restriction by the wood. 69 lava caves have been found in the flow and new caves are still being discovered. Several other lava flows of Mt. Fuji bear lava caves, and in all over 111 are now known. Some of the caves are compound treemolds formed after huge trees were knocked down and the trunks were buried in the flowing lava. Many of the fallen trees crossed over and made complex systems of tree trunk mold chains.

Mt. Fuji is accessible from Gotenba City at the eastern foot, on the Tomei expressway, JR and Odakyu Railway lines, and from Fuji City at the southern foot, on Tokaido and Shinkansen lines and the Tomei expressway. It is also possible to go from Fujiyoshida City in the north using the Chuo expressway and Fujikyukou Railway line. The foot of the mountain is densely popueated with about one million people. The northern foot is a plateau with an altitude of 600-1000m and there are five lakes, Yamanaka, Kawaguchi, Sai, Shoji and Motosu, and has several resort places.

The geology and eruption history of Mt Fuji were studied by Professor H. Tsuya (1935, 1938, 1940, 1943, 1955, 1962, 1968, 1971, 1981) and by Professor H. Machida (1964, 1968, 1971, 1981). Recently Doctor N. Miyachi (1988) published his study on the volcanic activity of Mt. Fuji.

Professor Tsuya (1938) found that an old volcano Komitake is partly buried under Mt. Fuji and the top of this has appeared on the northern flank at an altitude of 2500m.

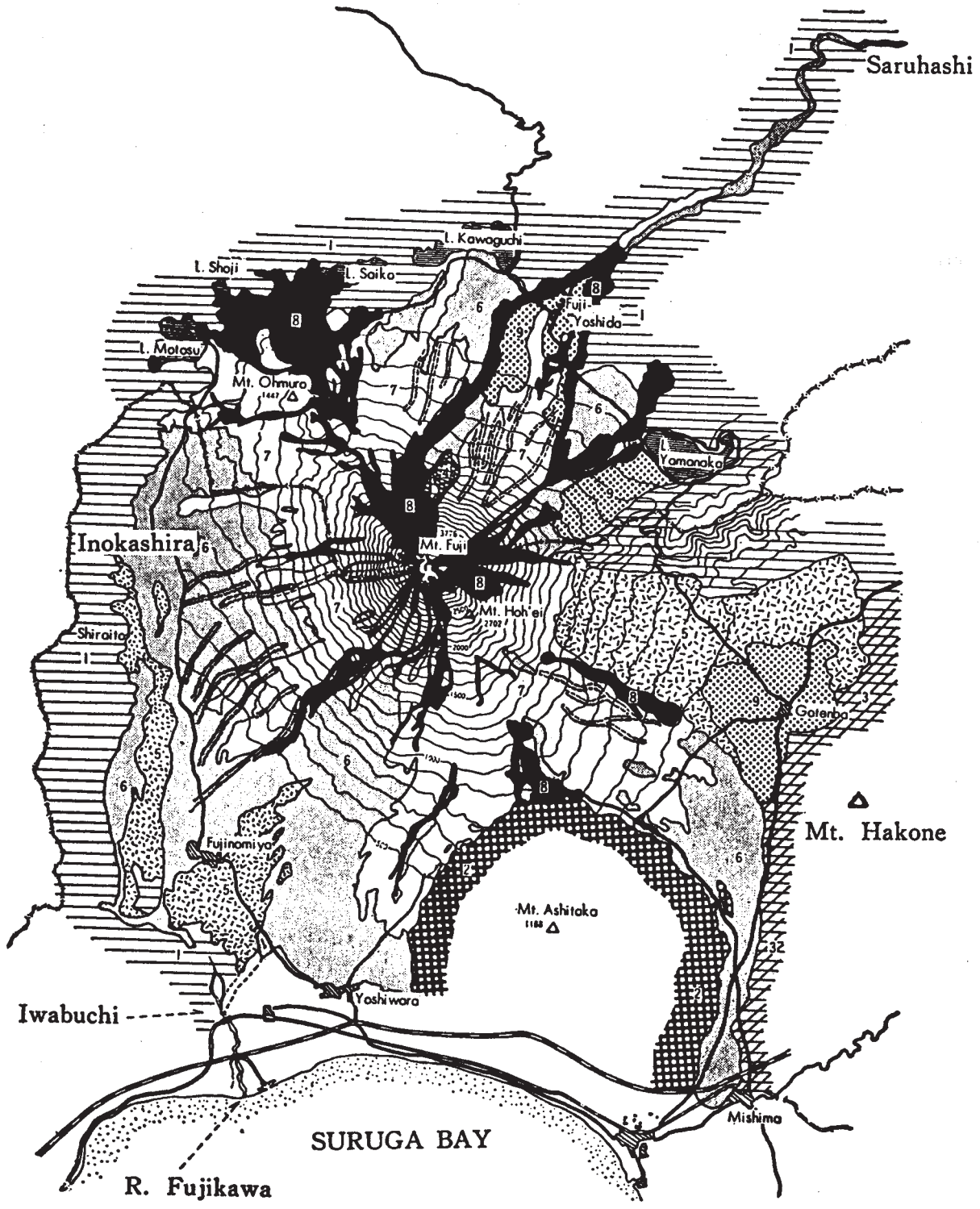

Figure 3-1 Geologic sketch map of Mt. Fuji and vicinity. After TSUYA (1971)
1. Tertiary formations 2. Volc. Ashitakayama 3. Volc. Hakoneyama 4. Volc. Komitake exposed partly on the north flank of Mt. Fuji 5. Volcanic mud-flows and other ejecta of Ko-Fuji (older Fuji) 6. Older ejecta of the present (younger) Fuji 7. Middle ejecta of the present Fuji 8. Younger ejecta (lava-flows mostly left uncovered with volcanic ash and other pyroclastics) 9. Volcanic ash and alluvial fan deposits

Komitake is actually a hump near the terminus of Subaru-line driveway where komitake Shrine is situated. The northern slope of Komitake is grooved by many small gullies, distinctly different from smooth flank slopes elsewhere. Professor Tsuya examined the laves exposed on the Komitake flanks and found they are of different rock types compared with the lavas of Mt. Fuji.

Ashitakayama Volcano is situated 15km south of Mt. Fuji, the highest peak of which is 1504m, while the saddle between Mt. Fuji where Jurigi Village is located is 800m above sea level. Ashitakayama Volcano is a somewhat dissected cone and the lavas are dated between 100,000 to 200,000 years old, consisting of an early basaltic cone and later andesites covering the cone. Though Komitake lava has not been dated, the rock resembles some Ashitakayama rocks and the dissection states of these volcanoes are similar, so possibly they are of the same age group.

Professor Tsuya divided the Mt. Fuji activity into older and younger stages, calling the older stage volcano "Older Fuji" and the younger stage "Younger Fuji". The Old Fuji is characterised by mudflows distributed at the south-west, east and northern foot of Mt. Fuji, and by sporadic exposures of oxidised aglutinates on the flank, as well as by tuff breccia 250m under the surface excavated in the tunnel dug for finding water at the south-eastern flank at 1040m above sea level.

The Older Fuji mudflows were dated by the carbon 14 method, showing between 16,000 and 24,000 BP. As this period corresponds to the last glacial era and at the time Mt. Fuji must have had an ice cap on its peak and an eruption of hot ejecta causing a flood by melting the ice cap and the flood gouged flank yielded mudflow similar to those of Nevado del Ruiz Volcano in Columbia when it erupted in 1985.

Professor Machida studied thick tephra beds east of Mt. Fuji. He recognised several thin rhyolitic-dacitic tephra among the Mt. Fuji origin tephra and they were then identified with southern Kyusyu origin tephra and Kiso-Ontake origin tephra. Akahoya tephra from Kikai caldera off the south of Kyusyu(6300 BP), Aira-Tanzawa tephra from Aira caldera in southern Kyusyu(22000 BP), and Pm-1 tephra from Kiso-Ontake Volcano in the Northern Alps of Japan (about 80000 years old) were identified among them. As Pm-1 tephra was found near the bottom of the tephra sequence the activity of Mt. Fuji must

have commenced about 80000 years ago.

The tephra sequence shown in the Older Fuji stage of volcanic activity has been very consistent materially and in effusive rate. However, it shows a calm period existed 9000 to 5000 years ago represented by a fume rich band in the tephra beds. The Akahoya tephra is found in the upper part of the dark band rich in carbonaceous meterial. Professor Machida called the dark band "Fuji darksoil".

Professor Tsuya(1968, 1971)divided "Younger Fuji" ejecta into older, middle and younger ejecta, and discriminated between more than 100 lava flows. The older ejecta is characterised by large 5-10mm size plagioclase phenocrysts and large scale lava flow of this age are distributed at the south-west, south-east and northern foot areas. Cave-bearing Obuchi flow has not been dated but this lava flowed underneath the Alluvial material reaching a level of -120m, confirmed by drilled water well data. This shows the Obuchi lava flowed out before the deposition of the Alluvial material, when sea level was -120m or so in the glacial period, probably some 15000 years ago.

The Mishima lava flow at the south-east foot is cave-bearing, which has been dated at 10490 BP. Motomurayama lava flow has been dated at 9350 BP and Saruhashi lava flow at the northern foot which is the longest lava flow reaching 35km from the summit, has been dated at 8530 BP. From these dating data, it seems large quantities of lava effused in the period around 10000 years ago.

Combined with the tephra evidence of the quiescent period 9000 to 5000 years ago, it is likely that Mt. Fuji erupted a gread amount of lava between 15000 to 9000 years ago and then the activity decreased for four thousand years. This rise and fall of activity may be related to the post glacial sea level rise which added a huge burden to the island arc crust and caused large amounts of magma production by a squeezing effect on the upper mantle under the crust, and when the sea level reached maximum and stabilised at that level. Around 9000 years ago magma production temporarily slowed down after the excess squeeze out period.

The cave-bearing flow of Mt. Fuji is almost restricted to the older lavas of the younger Fuji stage, with the major exception of Aokigahara lava flow dated 864 AD. Lava caves are found in Obuchi, Mannobara, Zunazawa, Mishima and Futagoyama flows of the older ejecta stage.

Table 3-1 List of parasitic Cones of Mt. Fuji. After Miyachi (1988).

Name	Stage of formation	Name	Stage of formation
1. Hoei craters	SS (1707 AD)	29. Kenmarubi crater	SS (10 Century)
2. Futatsu-zuka	S	30. Ohnagaremaruyama	S
3. Akatsuka	S	31. Oniwa & Okumiwa	S
4. Nishifutatsuzuka	S	32. Nishi-okuniwa	M
5. Jiroemonzuka	M	33. Kosukemaru	M
6. Katabutayama (S)	O	34. Nishikohsukemaru	M
7. Kitakansuyama	S (ca. 6 Century)	35. Hakkenyama	M
8. Kansuyama	S (ca. 6 Century)	36. Sawarayama	MO
9. Kurozuka	S (3-4 Century ?)	37. Usuyama	M
10. Hiratsuka	M	38. Hakudairyuou	SS (8 Century ?)
11. Takayama	SO	39. Kori-ike	SS (8 Century ?)
12. Asagizuka	SO	40. Kitakori-ike	S
13. Higashiusuzuka	M	41. Yumiizuka	M
14. Koshikirizuka	M	42. Katabutayama (N)	M
15. Nishikurozuka	MO	43. Shikanokashira	M
16. Takahachiyama	S (ca. 5 Century)	44. Tsugaoyama	M
17. Nishiusuzuka	M	45. Ohmuroyama	SO
18. Nishiasagizuka	SS	46. Kooriana crater	SS (9 Century)
19. Ohbuchi crater	S (ca. 3 Century)	47. Igadonoyama	SS (9 Century)
20. Myogatake	M	48. Tenjinyama	SS (9 Century)
21. Shiratuuka	M	49. Nagaoyama	SS (864 AD)
22. Hinokizuka	M	50. Ohhirayama	S
23. Futagoyama	O	51. Sajikiyama	S
24. Toyazuka	O	52. Higashiken	M
25. Inusuzumiyama	O	53. Nishiken	S
26. Nagayama	M	54. Gannoana crater	SO
27. Futatsuyama	O	55. Ishizuka	SS (864 AD)
28. Ushigakubo crater	SS (11 Century)	56. Ohusu & Kousu	MO

SS=250-1200y. B. P., S=1200-2000y. B. P., SO=2000-3000y. B. P., M=3000-4500y. B. P., MO=4500-8000y. B. P., O=8000-11000y. B. P.

Since 5000 years ago, the activity of Mt. Fuji has risen again and air fall tephra and lava effused from the summit crater and flank openings. Professor Tsuya's middle ejecta of the younger Fuji corresponds to effusives from 5000 to 2000 years ago.

A number of lava flows and several parasitic cones (Hiratsuka, Koshikirizuka, Higashi-usuzuka, Hinokizuka, Kosukemaru, Katabutayama (North) and Yumiizuka) formed between the years 4500 and 3000 BP and they are covered by later air fall tephra of Zunazawa, Ohsawa and Ohmuro scoria beds. There are some 60 parasitic cones, and about one third of them formed in this stage. (see Table 3-1, Stage M).

About 3000 years ago, a Plinian eruption from the summit crater and from Ohmuro-yama successively ocurred with about 3km³ of ejecta.

About 2500 years ago, there was a large scale collapse on the south-eastern face causing Gotenba debris flow to deposit which has been dated at 2360 BP (Machida, 1964) abd 2580 BP (Miyachi, 1988). The total quantity of collapsed material is 1-2km³ and is somewhat less than the debris left by the 1980 Mt. St. Helens event, which was 2.6km³

Miyachi (1988) showed a 2000 year old 0.5m³ scale tephra (Yubune-daini scoria bed) and Asagizuka and Gannoana crater activity took place at about the same time. Gannoana lava flow from the Gannoana crater bears Kuzureana cave.

Historical records of Mt. Fuji eruptions start at 781 AD and some twenty activities were recorded in 1200 years. According to the records, Mt. Fuji was very active between the period 781 to 1083, then suddenly quietened down for 400 years until 1511, then five eruptions were recorded between 1511 and 1709 and since then no eminent activity was recorded for 290 years (Table 3-2).

In the 800-802 eruption (also called the Enryaku eruption), effused air fall from the summit crater choked the Tokaido road passed through Gotenba. The Hakone route was opened instead and this has become the major Tokaido route since then.

The 864-865 eruption (also called the Johgan eruption) occurred at the northern flank's new openings now called Nagaoyama and Ishizuka parasitic cones, from which approximately 5×10^8 tons of lava flowed out and covered an area of some 30Km². The lava went into Motosu and Semoumi (Saiko of today) and partly covered them. The area covered by the lava flow now called Aokigahara wood-sea is almost impenetrable and there 69 caves were discovered. A few new caves are still being discovered every year. Professor

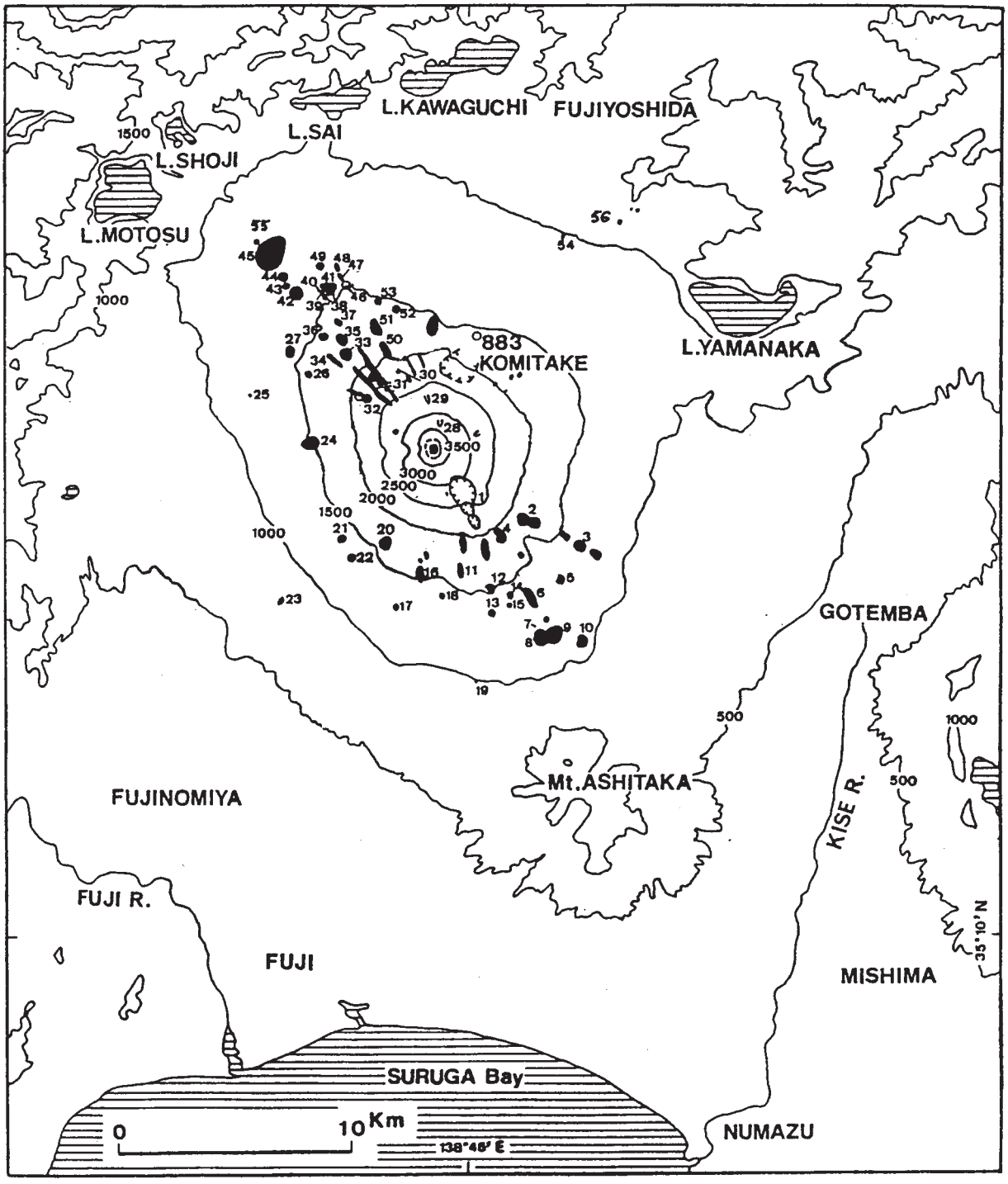

図 3-2　富士山の寄生火山・側火口の分布。　宮地(1988)による。
寄生火山等の傍らの小番号が、表 3-1　の番号に対応。

Fig. 3-2 Parasitic cones and flank craters of Mt. Fuji. After MIYACHI(1988)
Small size numbers in the figure showing sites are correspond to the numbers on Table 3-1.

Tsuya(1972)and Mr. Ogawa (1972) described these caves and interpreted their formation mechanisms.

The 937 eruption (also called the shohei eruption) records indicated lava flowed into a lake and this incident is likely to correspond to Takamarubi and Hinokimarubi lava flows which flowed into Yamanaka lake causing a rise in its water level.

The 1707 eruption (also called the Hoei eruption) was a large scale Plinian eruption effused from southern flank openings, with 13×10^8 tons or $0.8km^3$ of tephre distributed to the east as air fall deposits. The 16 days of eruption started in the early afternoon when a huge white smoke pillar blew up and deposited white dactic pumice lapilli. After four hours the colour of the smoke pillar distinctly became darker and dark coloured basic andesite lapilli was deposited. The plinian phase continuously lasted for four days from the three crater chain and activity became rather intermittent before suddenly stopping when a strong tremor occurred and a hump between the first and second crater was formed on the 16th day of eruption. The hump was then named Hoei-zan, the top of which is 2700m above sea level.

A large number of documents are available concerned with this event and it seemed there were no casualties at the time of the eruption but later there were cases of severe starvation among the people who lived in the devastated area. The 3m thich lapilli deposit of the 1707 eruption can still be observed in the Subashiri district at the eastern foot of Mt. Fuji having a distinct 15cm thick basal white pumiceous lapilli bed. Some 5-10cm of ash fall was recorded in Tokyo, or Edo as it was known at the time. This eruption was extraordinary in four aspects: as dacitic material effused at an early stage, no lava effused and it was a totally Plinian phase eruption, the eruption was preceded just 49 days by the great Tokai earthquake of M8.4(known as the great Hoei earthquake), and because it was the largest eruption in 3,000 years.

The historical record shows that the activity of Mt. Fuji is intermittent with rather long quiescent intervals. Since 1083 the only large eruption was that of 1707 and this activity did not contribute to the construction of the volcanic cone, and thus Mt. Fuji has only been subjected to erosional force for about 1000 years.

A large scar or gouge developed on the western slope of the summit and is called "Ohsawa-kuzure". The deep gully is betwen 3500 and 2500m in altitude and the estimated loss is of $0.02km^3$ or the equivalent of 4×10^7 tons of rock from the flank. A narrow gouge combines Ohsawa-kuzure to an alluvial fan at the foot, (900m below)where about 3

$\times 10^7$ tons of debris rests(Figure 3-3). The early debris bed was dated at 950 BP, which indicates the Ohsawa-kuzure started to collapse around 1000 AD. There are two records of Mt. Fuji collapse, in 1181 and 1331 AD, and the latter record describes "several hundred metres of collapse near the summit occurred at an earthquake" and this was most likely to be a collapse which occurred at Ohsawa-kuzure.

Some people are keen on trying to prevent the top of Ohsawa-kuzure eroding, as they are afraid the advanced erosion may cause deformation in summit symmetry. However, it is likely to take at least 1000 years before the gully cuts into the summit and deforms the symmetry, and it may be more probable that within the next 1,000 years an eruption of the summit crater will pour out lava along Ohsawa-kuzure which will restore the scar.

Only at times of heavy rainfall every several years, debris at the bottom of Ohsawa -kuzure is carried down in the form of a mudflow to the alluvial fan. Such a mass transportation was first observed in 1958 when some 100,000 tons of debris flowed down to the fan at about 300mm of rainfall. Recently a remote control TV camera was installed and all such mudflows are observsable.

The National Centre for Preventing Disasters set microseismographs at Shimobe, 20km west of Mt. Fuji, in 1979. On accumulating the records observed it was revealed that microseismicity continuously occurred under Mt. Fuji, in high and low frequencies. The Earthquake Research Institute of Tokyo University then installed geophysical equipment in a tunnel at the south-western flank of Mt. Fuji in 1982.

In 1939 a swarm earthquake occuring under Mt. Fuji was felt, but since then there have been no felt earthquakes of Mt, Fuji recorded. In 1987 seismicity under Mt. Fuji became somewhat active, including rather eminent low frequency tremors characteristic of active volcanoes, then a few felt earthquakes were observed at the summit observatory.

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Table 3-2 Historical Records of Mt. Fuji Eruptions

781(Ten oh 1) Volcanic ash fell like rain, trees killed. (Shoku-Nihongi).

800-802(Enryaku 19-21) Summit eruption darkened daytime, and fire lit the night sky. Ashigara route was closed because of the ash fall, and Hakone route was newly opened. (Nihon-koki).

826(Tencho 3) Eruption. (Samukawa Shrine record).

859(Johgan 1) Eruption? (Ruiju-kokushi).

864-865(Johgan 6-7) 3 earthquakes occurred and eruption started with a 70m high fire column. Lava flowed into Motosu and Senoumi lakes, part of it directed to Kawaguchi lake. Many houses were demolished. (Sandai-Jitsuroku).

870(Johgan 12) Fierce eruption at the summit. (Samukawa Shrine record)

932(Shohei 2) Fierce eruption with the ejection of magma and scoria which caused Omiya-Sengen shrine to burn down. (Fujishi).

937(Shohei 7) God's fire buried the lake. (Nihonkiryaku).

952(Tenryaku 6) Eruption at the north-eastern side of Fuji.

993(Syoureki 4) North-eastern flank eruption.

1017(Kannin 1) Eruption occurred from three openings on the northern flank. (Fujishi).

1033(Chogen 6) Fire arose at the summit and then down to the foot. (Nipponkiryaku).

1083(Eiho 3) Eruption. (Husoryakki). Lava and scoria ejected from seven openings. Mt. Fuji volcanic activity ceased from then on. (Fujishi).

1331(Genko 1) Earthquake caused a Fuji summit collapse of several hundred metres. (Taiheiki).

1511(Eisho 8) Fuji Kamaiwa burned. (Myohoji-kyuki).

1560(Eiroku 3) Eruption. (Nipponsaiishi).

1700(Genroku 13) Eruption. (Nipponsaiishi).

1707(Hoei 4) Swarm earthquake followed by eruption on the next day on the southern flank. Four hours later the white cloud turned darker. Suddenly stopped on the 16th day. (Many references).

1709(Hoei 5) Fuji erupted again. (Kokufu-nenpyo).

1825(Bunsei 8) Swarm earthquake. (Kinoene-yawa).

1854(Ansei 1) Minor eruption?

1939(Showa 14) Swarm earthquake. (Nihon-Katsukazan-soran).

1987(Showa 62) Swarm earthquake. (Jour. Group. Pred. Volc. Activity).