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HELIUM ISOTOPES AS TRACERS OF INCIPIENT MAGMATISM FOLLOWING THE 1996/1997 SEISMO-TECTONIC CRISIS ON NISYROS VOLCANO (GREECE)

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The islands of Nisyros, Santorini, Milos and Methana are considered today the most active areas of the Hellenic Island arc in terms of a potential volcanic reactivation. Although the last volcanic activity on Nisyros dates back at least 25 000 years, the geodynamic activity, expressed by high seismic unrest, fumarolic activity and hydrothermal explosions is continuously present. Violent earthquakes, gas detonations and fire accompanied the most recent hydroclastic eruptions in 1873 and 1888. The latter effects are due to high gas emanations of H2S, CO2, H2 and CH4 from fracture zones, which cut the caldera and extend towards NNW through the vicinity of the village of Mandraki into the island of Yali and even towards Kos. In 1996 and in 1997 high-seismic activity (magnitudes of earthquakes up to 5.5 on the Richter scale) occurred on Nisyros and was accompanied by increased tectonic and fumarolic activity. In this respect, the scheme of events as comparable with the violent activity in 1873 and 1888, required serious examination. Besides the permanent residents of the island of Nisyros, several hundred of tourists enter the hydrothermal field of the Nisyros caldera daily without awareness of the entire risk situation. The high 3He/4He ratios of 5.9 to 7.5 x 10E-6 in the Nisyros fumarolic condensates, sampled in October 1997 after the long period of strong earthquake activity, overlap entirely with the helium isotopic ratios measured in the high temperature fumaroles at Vulcano island (Aoelian island arc) during the magmatic/volcanic crisis in 1988 and 1989. In the case of Nisyros, it may be related to magma degassing, indicating an influx of the gases from a replenished magma reservoir at shallow depth.

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Presiding Chair: Yasunori Nishida (Departmant of Earth and Plantary Sciences, Hokkaido University, Japan)
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AN INTEGRATED APPROACH TO THREE-DIMENSIONAL STRATIGRAPHIC RECONSTRUCTIONS OF LONG-LIVED QUATERNARY ARC VOLCANOES: TATARA-SAN PEDRO COMPLEX (TSPC), 36° S, CHILEAN ANDES

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The TSPC is a large frontal arc center of the Andean Southern Volcanic Zone dissected on all flanks by glacial valleys exposing the eruptive products of seven edifices ranging in age from 930 ka to Holocene (Singer et al, 1997; GSA Bull). Sequences older than 200 ka are remnants of spatially overlapping volcanoes reduced in volume (50-90 %) by glaciation and sector collapse, and preserved remnants generally record short durations relative to intervening lacunae. Digitised photogrammetric projections based on stereo imagery of canyon walls represent stratigraphic relations and the geometries of erosion surfaces in far greater detail and more accurately than conventional mapping would permit. The internal stratigraphy of several sequences has been reconstructed on the basis of geochemical data (650 samples collected in 25 flow-by-flow canyon sections) plus photogrammetric, geochronologic and paleomagnetic constraints. This composite stratigraphy is far more complete than the records present in any single section due to the eccentric distributions of the products of consecutive eruptive events and the effects of erosion. Many stratigraphic successions record temporal trends lacking in evidence for progressive differentiation. The resulting constraints on petrologic models are far different than if apparently co-magmatic lavas were assumed to reflect single-stage differentiation. Most eruptive events reflect arrival of small quantities (<1-2 km3) of diverse mafic magma into shallow conduit-reservoir systems where they mixed in varying proportions with variably evolved resident magmas.

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EVOLUTION OF MONTSERRAT USING 40AR/39AR GEOCHRONOLOGY

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40Ar/39Ar ages of volcanic rocks representing the major stratigraphic units of Montserrat facilitate a substantial reinterpretation of the evolution of the island. These ages are more precise and significantly different from existing conventional K-Ar ages. We identify three distinct volcanic centres: Silver Hills (c.1.2 to 2.6 Ma); Centre Hills (at least c.950 to 550 ka); Soufriere Hills (at least c.150 ka to present). Volcanism on Montserrat has migrated southwards through time, at a time averaged rate of c. 6 km/m.y. parallel to the trench and c.2 km/m.y. away from the trench, consistent with work elsewhere in the arc.
Six new ages give insights into the life cycle of the youngest centre. The history of the currently active Soufriere Hills Volcano, dominated by andesitic lava dome eruptions, is extended back to 150 ±3 ka (1_ error), well beyond the oldest radiocarbon age of 31.6 ±0.2 ka. We estimate its time-averaged eruption rate to be c.0.0015 m3/s. Ages for three pyroclastic flow deposits and two domes indicate that preservation of domes is incomplete, and large scale collapse may play a significant role in the volcano's history.
An age of 959 ±19 ka from Roche's Bluff, south-east of Perches dome (Soufriere Hills), facilitates the interpretation of this intensely disrupted pyroclastic sequence as part of the uplifted submarine fan of the Centre Hills. We further propose that St George's Hill and Garibaldi Hill to the north-west of the Soufriere Hills are uplifted pyroclastic sequences. An age of 282 ±8 ka from Garibaldi Hill suggests this sequence may represent the early stages of the Soufriere Hills.
Step heating experiments on material from the current eruption give an age indistinguishable from zero (21 ±22 ka) for groundmass separates but an age significantly greater than zero (426 ±95 ka) for separated plagioclase phenocrysts, indicating no extraneous argon in the groundmass but xenocrysts in the plagioclase phenocrysts. Thus, groundmass separates should be used whenever possible for dating crystal-rich andesites.

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SHALLOW SEISMICITY AND CRUSTAL DEFORMATION ASSOCIATED WITH THE 1998 INTRUSION EVENT AT IWATE VOLCANO, NORTH-EASTERN JAPAN

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Since we first observed volcanic tremors in Iwate volcano in September 1995, we have gradually extended seismic stations in and around the volcano and, at the present; we have 20 stations in the area of 15 km x 20 km. We have succeeded to catch a new seismic activity and revealed that the activity is related with intrusion of magmatic fluid beneath the volcano. The activity had started in January 1998 beneath a crater rim adjoining the west of the summit. Magnitudes of the events were less than 0.5, focal depths were 2 - 6 km, and the occurrence rate of the earthquakes was about 10 per month till the middle of March. Suddenly on March 20, the first earthquake swarm had occurred. The source region had extended westward up to 2 km in distance, magnitudes had grown to 0.5 - 1.0, and focal depth had moved to 0-2 km. After this swarm, the rate had increased to about 50 per month till the middle of April. On April 29, the second swarm had occurred. Source region had extended westward more, and earthquakes with magnitude greater than 2 had occurred. After the second swarm, the rate had increased to about 150 per month. Since June, the source region of the seismic activity had gradually extended westward with lapse of time. Then the last geometry of source region is a rectangular shape with 10-km length from east to west and 3km width from north to south in August. Critical comparisons of the above seismicity with crustal deformations observed by borehole strain and tilt meters at 3 stations and GPS (Ueki et al., 1999) clarified upward and westward movements of a pressure source beneath the volcano. Thus we conclude that the both activities are induced from intrusion of fluid like magma. At the final stage of the intrusion event, on September 3, an earthquake M6.1 has occurred at the point close to the western tip of the seismic source region. The mechanism of the earthquake is the explained by a thrust type fault presumably affected by the above intrusion.

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APPLICATIONS OF GPS GEODESY ON ACTIVE STRATO-VOLCANOES: CASE STUDIES OF SOUFRIERE HILLS, MONTSERRAT, POPOCATEPETL, MEXICO, AND MISTI, PERU

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Ground deformation is important for monitoring volcanoes for hazard assessment and elucidation of sub-surface magmatic processes. GPS geodesy is now used exclusively or in concert with traditional deformation techniques, such as telemetered electronic tiltmeters, precision leveling, and electronic distance measurement, to study volcanic systems at different stages of evolution. While each technique is useful, GPS geodesy has some unique characteristics, which makes it a powerful tool for the study of volcanoes. Continuous GPS (CGPS) systems have special difficulties related to maintenance during intense volcanic activity. We report here results obtained from 1995 to 1999 using mixed-mode and CGPS geodesy from three stratovolcanoes: Soufriere Hills (SH), Montserrat; Popocatepetl (Popo), Mexico; and Misti, Peru. CGPS systems have been deployed at SH and Popo since mid 1996 and Misti since late 1998. In the case of Soufriere Hills, GPS data span the period of phreato-magmatic venting, andesitic lava effusion, dome building and collapse, vulcanian to sub-plinian explosions, and apparent quiescence. CGPS data from Popo span the period of high SO2 gas emission and venting. While CGPS provides dense temporal sampling, additional mixed-mode and campaign style GPS data are essential to constrain spatially variable deformation fields at the scale of 1 to 10 km. Data spanning distinct eruption events and changes in eruption magnitude or style provide constraints on sub-surface deformation sources. Magma storage depths, volumes, and viscosities may be deduced using elastic and finite-element models.

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REMOTE SENSING AND GPS FOR DIGITAL TERRAIN MODELS EXTRACTION: VALIDATION AND COMPARISON OF OBSERVATIONS FOR VOLCANIC MODELLING

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Satellite and airborne remote sensed images provide a powerful tool for Digital Terrain Model (DTM) extraction especially when coupled with the use of Global Positioning System (GPS) techniques for georeferencing and validating results. 3D topographic observations acquired periodically over volcanic areas can be used for deformation monitoring and morphological changes detection. Different studies for monitoring and modelling volcanic processes can be performed depending on the quality and the resolution of the available DTM.
The performance of different methods for DTM extraction are analysed by comparing results over a test area on the Vulcano Island: high resolution DTM obtained by automatic digital processing of airborne stereoimages from a photogrammetric camera (Wild RC20) and a High Resolution Stereo Camera (HRSC) are analysed and compared. A SAR interferometric DTM is also derived in support of studies with low accuracy requirements, such as those dedicated to landslides and lava flows monitoring. High accurate height profiles from a GPS kinematic ground survey is used for DTM validation.

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DYNAMIC DEFORMATION OF ETNA VOLCANO OBSERVED BY GPS AND SAR INTERFEROMETRY

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Synthetic aperture radar (SAR) interferometry and GPS have shown that during the quiescent period from 1993-1995 Mt. Etna volcano, Italy inflated. Since the initiation of eruptive activity since late 1995 the deformation has been more contentious. We will explore the detailed deformation during the period from 1995-1996 spanning the late stages of inflation and the beginning of eruptive activity. We use SAR interferometry and GPS data to measure the volcano deformation. We invert the observed deformation for both simple point or tensile crack elastic sources or if warranted for a spheroidal pressure source. In particular, we will examine the evolution of the inflation and the transition to a lesser deflation observed at the end of 1995. We use ERS-1/2 SAR data from both ascending and descending passes to allow for dense temporalsampling of the deformation and to allow us to critically assess atmospheric noise.