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The Miocene Searchlight pluton (Nevada, USA) is a well-exposed, 12 km thick magma chamber. Previous work indicates it solidified in simple monotonic fashion. Crystal accumulation on the chamber floor, and downward propagation of a solidification front from the roof, resulted in felsic melt segregation in the interior. However, one small (3 km^2) relatively mafic part of the pluton (called Guzzler Gulch) has abundant chemical and textural variation at a scale not observed elsewhere in Searchlight pluton (cm to m). This unit intrudes through the gradation between the lower cumulate and the middle granite. The main rock type is an equigranular hornblende diorite, but fine-grained hornblende gabbro is also common. Contacts of mafic rocks with surrounding granite are gradational, and mutually crosscutting relations are seen where gabbros and diorites intrude granite and are back-veined by granitic dikes. Later gabbros are also seen cutting earlier gabbros. A number of observations suggest that the mafic injections occurred when the Searchlight magma chamber was waning: (1) Guzzler Gulch unit is intruded into granite that is at least partly cumulate, (high modal alkali feldspar displaying originally horizontal layering); (2) inclusions of the feldspar-rich, cumulate granite, up to 5 m in diameter, are completely surrounded by hornblende diorite, and are inferred to be autostoped blocks of mostly solidified granite; (3) irregular-shaped gabbroic pods several m's in diameter are also intruded into the cumulate granite, but hybrid zones are narrow (a few m's), and consist of heterogeneous light and dark banded rocks with abundant mafic enclaves; (4) the originally horizontal cumulate fabric in the granite is locally disrupted by, and sometimes reoriented, into parallelism with the contact between the Guzzler Gulch mass and the surrounding granite; (5) geochemical data are consistent with local hybridization, but hybrids are chemically quite heterogeneous on the scale of the entire Guzzler Gulch body; (6) Ion-microprobe $^{206}Pb/^{238}U$ zircon ages from a hybrid diorite and a coarse-grained gabbro are 16.2±0.2 Ma (MSWD = 2.7; N=17) and 15.9±0.3 (MSWD = 2.2; N=19), respectively, which overlap within error the 15.8±0.4 Ma zircon age of the late-crystallizing middle granite unit of the main Searchlight pluton. The Guzzler Gulch area of the Searchlight pluton appears to capture the process of failed rejuvenation of an intermediate to felsic magma chamber that was nearly solid. Physical evidence for physical disruption of crystal-rich, or even near-solidus magma by repeated mafic input (e.g. autostoping and engulfment of cumulate blocks) was accompanied by quite localized remelting of mush and/or reheating of the felsic cumulates and spatially restricted hybridization. Thus during the time of intrusion of the Guzzler Gulch mass, the Searchlight magma chamber was incapable of thorough mixing.

V51I-0399 0830h POSTER

Au-Skarn Mineralization: Constraints from LA-ICP-MS U-Pb Zircon Dating

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In situ U-Pb zircon geochronology by laser ablation ICP-MS was performed on samples from the intrusive rocks of the Buckhorn Mountain, Washington in order to constrain the age of the Crown Jewel Au-skarn deposit. The analyses were conducted at Washington State University using a ThermoFinnigan Element2 single collector, high resolution magnetic sector ICP-MS, and a New Wave UP 213 Nd-YAG (213 nm) laser ablation system. The analytical parameters included a repetition rate of 10 Hz, a 40 microns spot size, and a total analysis time of 30 seconds per spot. A 94-35 cascade standard was used to bracket the samples. Two distinct $^{206}Pb/^{238}$ U ages were obtained, 52.3 Ma ± 1.6, 165.0 Ma ± 5.9, 163.4 ± 5.7, and 169.8 ± 12.1 (all errors are 2 sigma). These ages represent distinct magmatic events occuring during the two main tectonic periods in the region. The oldest age (∼165 Ma) is associated with the accretion of the Quesnel terrain during the Middle Jurassic while the younger age (∼52 Ma) represents the magmatism during the Eocene extension that is well represented by the Challis Volcanics in the vicinity. The Jurassic ages were obtained in one sample from a deformed granodiorite dike and two samples from the main granodiorite intrusive facies that, based on the skarn mineralogy zonation, is spatially associated with the skarn. The Eocene intrusive unit was intercepted in one drill core but is clearly distinct from the granodiorites both geochemically and mineralogically. This facies is more an adamellite, with a distinctive pinkish colour due to a K-spar alteration. It is higher in silica, and depleted in compatible elements (Ca, Fe, Ti, Mg, P, Y, and V) relative to the granodiorite. Geochemically the granodiorite has a composition typical of plutons associated with Au-skarns worldwide. Because Au mineralization is erratically distributed and does not correlate with any of the skarn mineralogy, a question can be raised. Does the Au mineralization have any connection with the more recent intrusive event? Future work will be conducted in order to clarify this question.

V51J MCC: Level 1 Friday 0830h

The Changing Shapes of Active Volcanoes: Volcano Geodesy I Posters

(joint with G)

Presiding: **M P Poland,** U.S. Geological Survey

V51J-0400 0830h POSTER

Analysis of mud volcanoes on the Absheron Peninsula, Azerbaijan using InSAR

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A set of Synthetic Aperture Radar data covering the Absheron Peninsula is processed using interferometry (InSAR) to generate a detailed digital elevation map of the region and to measure possible surface deformations. The dataset includes five ERS-1 and ERS-2 scenes from 1996 though 1999 centered near Baku and 8 Radarsat images from 1999. The radar has a wavelength of 5.66 cm allowing theoretical resolution along the line of sight of the satellite of surface deformations on the order of mm to cm. Sources of potential surface deformation are recent earthquakes, mud volcanism, groundwater changes, and hydrocarbon withdrawal. We also use optical satellite images (Advanced Spaceborne Thermal Emission and Reflection - ASTER) in addition to ground truth data. Initial InSAR processing used a digital elevation model (DEM) based on the combination of a global DEM with a high resolution DEM based on ASTER stereo optical data. This DEM was then refined with radar pairs possessing short temporal baselines. Correlation over the area was fair with moderate to low correlation over a time period of 2 years. Preliminary results using the initial DEM show no clear indications (> 10 cm line-of-sight) of deformation over known mud volcanoes. Modeling of likely fluid movement associated with the mud volcanoes indicates that the lack of observed signal places constraints on the depth of increased pressure and chamber size. Modeling of the two large (Mw 6.8 and 6.5) earthquakes near Baku in November 2000 using global catalog locations and focal mechanisms indicates that the deformation from these events should be observable onshore using InSAR.

V51J-0401 0830h POSTER

Repeated Seafloor Geodetic Observation west off Miyake-jima volcanic island

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An intensive earthquake swarm started under Miyake-jima island, 180 km south off Japan main island, on June 26, 2000. The earthquake swarm migrated towards northwest off Miyake-jima island, where numerous earthquakes, more than 100,000, were detected within about two months and an extensive crustal deformation was observed by on-land geodetic observations. Inst. of Industrial Science, Univ. of Tokyo and Hydrographic and Oceanographic Dept, Japan Coast Guard deployed three seafloor geodetic reference stations (St.A, St.B & St.C) in triangle area surrounded by three islands, Miyake-jima, Nii-jima and Kouzu-jima islands, in November and December, 2000, and have been conducting observations using these three stations to monitor seafloor deformation for the better understandings of underground magmatic activities. The observations have been conducted thirteen times until present. Fast and quickly varying ocean current in this area prevented us from stable observation. The surface current makes the pole, which connects the GPS antenna and the ship-board transducer, bend. This bending of the pole gave uncertainty to the analyses of locating the positions of the seafloor geodetic reference stations. The pole was replaced new, more rigid pole to overcome the problem in August 2002. The first observation with this new system was conducted at the reference station in the Sagami-bay. Smaller amount of bending with the new pole than that with the old one against both roll and pitch components could be seen in the data from this observation. This shows that the replacement of the pole provided stability to the observation system. We started to adopt the new system to the observation at the three stations west-off Miyake-jima island area, too. Station C, that is located nearest one to the Miyake-jima island, is one where we had most frequent observation after improvement of the system. The observations with the new system have been conducted four times in September, December 2002, April and August 2003 there. We have been processing and analyzing the data from these four observations at Station C. More stable analyses have been done with the data from the observations which the new system was employed than with ones observed by the old system. In this poster, we will present the repeatability of the observation system with the new pole, as well as discuss the preliminary results from them.

V51J-0402 0830h POSTER

Thickness distribution of a cooling pyroclastic flow deposit: Optimization using InSAR, FEMs, and an adaptive mesh algorithm

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We construct finite element models (FEMs) of a pyroclastic flow deposit (PFD) emplaced during the 1986 eruption of Augustine volcano, Alaska. Interferometric synthetic aperture radar (InSAR) imagery documents the consistent contraction of the PFD during 1992-2000. Three-dimensional problem domains of the FEMs include an elastic substrate overlain by a thermoelastic material representing the PFD. The geometry of the substrate is determined from a digital elevation model (DEM) and bathymetry data. The thickness of the PFD is initially determined from the difference between post- and pre-eruptive DEMs. Systematic prediction errors suggest the PFD thickness distribution, estimated from the DEM difference, is inaccurate. We combine InSAR images, FEMs, and an adaptive mesh algorithm to re-estimate the geometry of the PFD and optimize the thickness distribution for the PFD. Prediction errors from the FEM that includes an optimized PFD geometry are reduced by 20% with respect to those from an FEM that includes a PFD geometry derived from the DEM difference.

V51J-0403 0830h POSTER

Magma Supply Dynamics of Okmok Volcano Inferred From Interferometric SAR

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Okmok volcano, located in the central Aleutian arc, is a shield volcano topped with a 10-km-wide caldera. The caldera-forming eruptions occurred about 8000 and 2400 years ago. Historic eruptions occurred in 1931, 1936, 1938, 1943, 1945, 1958, 1960, 1981, 1983, 1986, 1988, and most recently during February-April 1997. More than 70 Interferometric SAR (InSAR) images were used to study the transient deformation of the volcano before, during, and after the 1997 eruption. Coeruptive deflation of 1.4 m was detected. Point-source models suggest a magma reservoir resides at a depth of 3 km beneath the center of the caldera, which is about 5 km northeast of the eruptive vent. Pre-eruptive inflation from 1992 to 1996 was observed. The inflation rate decreased from about 10 cm/year during 1992-1993 to a nearly negligible magnitude during 1995-1996. The post-eruption inflation rate during 1997 and 2002 generally decreased with time, although the rate during 2000-2001 was exceptionally low. The location of the magma source during the pre-, co-, and post-eruption inflation periods is essentially constant. Interferograms spanning 1997-2002 captured at least two distinct deformation processes: (1) volcano-wide inflation due to influx of magma into the reservoir and (2) subsidence

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of the 1997 lava flows most likely due to thermal contraction. By the summer of 2002, about 1/3 of the magma from the 1997 eruption was replenished within the shallow reservoir. The decaying inflation rate is consistent with a simple fluid flow model driven by a pressure gradient between a deeper magma source and the 3-km-deep shallow reservoir. Continuous monitoring of deformation at Okmok volcano will lead to an improved understanding on how this volcano works.

URL: http://edc.usgs.gov/Geo_Apps

V51J-0404 0830h POSTER

Constraining Source Parameters From Geodetic Observations During Unrest at the Campi Flegrei Caldera (Italy): a Case of Spherical vs. Extended Geometries in an Elastic Half-Space

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Unrest at the Campi Flegrei caldera (CFc) since 1981 has been associated with up to 1.8 meters of uplift between 1982 and 1984 followed by more than 0.9 meters of subsidence between 1984 and 2001, without any manifestation of eruptive volcanic activity. We have reanalysed previously published deformation and gravity data as well as new data obtained between 1994 and 2001 in order to constrain the position, depth and geometry of the source as well as its mass and volume changes. The vertical displacements have been inverted for i) a Mogi-type point source, ii) a Mogi-type spherical source, iii) a penny-shaped horizontal crack source and iv) a vertical prolate ellipsoidal source, all within an elastic homogeneous, isotropic half space. While both Mogi-type sources (located at a depth of 3 km) give excellent fits to the data, overpressures required to produce the observed surface inflation pattern are in excess of 250 MPa, at least one order of magnitude higher than the country rock tensile strength. We therefore express our concern at employing Mogi-type source geometries in order to account for both deformation and gravity changes measured at the CFc. Alternatively, inflation and deflation of both a horizontal penny-shaped crack and a vertical prolate ellipsoidal source located at a depth of 5.6 km beneath the centre of maximum vertical deformation provide an equally good fit to the data. The associated overpressures during inflation for both source models are found to be 20 and 6 MPa, respectively, which are within the limits of tensile strengths expected at a long-lived volcanic system. The analysis of horizontal displacements will provide a firm and definitive discrimination between the horizontal crack and the vertical ellipsoidal source models and permit quantification of mass and volume changes during the recent episode of unrest at the CFc.

V51J-0405 0830h POSTER

Seismic and Geodetic Unrest at Uturuncu Volcano, Bolivia

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A large-scale concentric pattern of deformation has been observed between 1992 and 2000 centered on Uturuncu Volcano, Bolivia from satellite geodetic surveys (Pritchard and Simons, 2002). A reconnaissance investigation by a team composed of scientists from Bolivia (M. Sunagua and R. Muranca), Chile (J. Clavero) , the USA (S. McNutt and M. Pritchard) and the UK (C Annen, M Humphreys, A le Friant, and R.S.J. Sparks) took place from 1-6 April 2003 to see if there were any other signs of volcanic unrest at Uturuncu. A single component vertical, one-second seismometer, was placed at five locations for periods up to 14 hours. Data were recorded at 100 samples per second on a laptop PC. Persistent low level seismicity was observed at all locations. The events were very similar to each other and most had a distinct P wave with a period of 0.1 sec and a clear S wave with longer period and higher amplitude. Nearly all the events at each station had similar S-P times, suggesting that the events came from mainly one source. Using bootstrapping methods we determine this to be from a source location on the north-west flank close to the center of deformation observed by satellite surveys. Several events with different S-P times and different waveforms suggest that two other sources exist within the volcanic edifice, but these cannot be located with the available data. The rate of volcanic earthquakes was up to 15 per hour; this is a surprisingly high rate for a dormant stratovolcano. The magnitudes were in the range 0.5 to 1.5 based on coda length. The sources were considered to be shallow within 3 - 4 km of the surface, although information on the velocity structure is not known. The summit region of Uturuncu (6,008 m) has an active fumarole field with substantial sulphur production and areas of silification. Temperatures in four fumaroles were measured at 79 - 80°C. A hot water spring on the NW flanks had a temperature of 20°C. The recent unrest manifested by substantial ground deformation, thermal activity and seismicity indicate that a magmatic system may still be present, and therefore further monitoring of this dormant volcano is warranted. Reference: M Pritchard and M Simons, "A satellite geodetic survey of large-scale deformation of volcanic centres in the Central Andes" Nature, 418, p167-170, 2002.

V51J-0406 0830h INVITED POSTER

CALIPSO Borehole Instrumentation Project at Soufriere Hills Volcano, Montserrat, BWI: Overview and Prospects

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Project **CALIPSO** (**C**aribbean **A**ndesite **L**ava **I**sland-volcano **P**recision **S**eismo-geodetic **O**bservatory) was developed in order to investigate the magmatic system at the exceedingly active Soufriere Hills Volcano (SHV), Montserrat. The collaborative project involves a number of institutions acting in partnership with the Montserrat Volcano Observatory (MVO), and is funded by NSF with a contribution to drilling costs provided by UK NERC. SHV remains active and dynamic after 7 years and is expected to remain so for the foreseeable future. Many aspects of andesite magmatic system dynamics remain poorly understood despite significant monitoring and research efforts, and **CALIPSO** is expected to improve our understanding of SHV and andesite systems generally. Drilling was carried out by DOSECC, Nov 02 to Mar 03. **CALIPSO** uses an integrated array of four strategically located 200-m boreholes, plus a few shallower holes and surface installations. The borehole instrument package is designed to have long life (decades) at moderately high temperatures. Each site includes a single-component,very broad band, Sacks-Evertson strainmeter, a three-component seismometer (about 1 Hz to 1 kHz), a Pinnacle Technologies tiltmeter, and a surface CGPS station with choke ring antenna. At one site a new CIW hot-hole strainmeter design, involving hydraulic sensors and no downhole electronics, has been used for the first time anywhere. Data will be streamed from the remote borehole sites using FreeWave telemetry coupled with Quanterra A/D converters. The borehole observatory is being fully integrated into the surface monitoring networks of the MVO and other PSU/U Ark monitor systems, enhancing the existing CGPS and surface broadband seismic-acoustic networks. These instruments are intended to probe changes in the andesitic volcanic system and underlying mafic sources with unprecedented sensitivity. Cyclic activity at a variety of timescales has been a feature of SHV volcanism, involving seismicity, ground deformation, dome activity and gas exhalation, at the about 10 hour time scale. Evidence exists also for 7 and/or 14 week, and some longer cycles, and the SHV eruption since 1995 is the fourth repetition of a 30 year cycle. The longer time scale cycles originate from the deeper plumbing system, and can sometimes be detected in the seismic, deformation and gas data. However, the data are close to the limit of detection by the MVO's surface monitoring network, and the need for a new monitoring approach to better investigate these longer-term cycles of deep origin has now been met by **CALIPSO**. Borehole instrumentation provides much reduced noise and the ability to locate effective stations farther from the volcano than possible with surface instruments, and both features aid the sampling of seismic and deformation signals from the deep transport, storage, and recharge systems. The design life of the borehole observatories is long, such that onset of the next 30 year cycle may be sampled after most PIs have passed on to their reward or otherwise, with some of us possibly obtaining personalised insights of the Mephistophelean magmatic environment.

V51J-0407 0830h POSTER

Borehole Strainmeters on Montserrat: the CALIPSO Project and the July 2003 Eruption.

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During November 2002 to February 2003, 4 borehole sites were established on Montserrat in order to provide data to investigate the on-going eruption of Soufriere Hills as part of the multi-institutional CALIPSO project that also included participation by the Monserrat Volcano Observatory. In the boreholes we installed a Sacks-Evertson strainmeter, a short period 3 component seismometer and a tiltmeter. Each site also included a GPS receiver. At one site, we installed for the first time a modified S-E strainmeter that is designed for long term operation under conditions of high temperature and high pressure. Straingrams of earthquakes indicate that all instruments were operating well. The dome building andesitic volcano has been active since before 1995 although the level of activity has been highly variable. Much of the island, including the capital Plymouth, has been devastated by pyroclastic and mud flows. A period of relative quiescence was interrupted last year as the dome built to greater heights than at any time during the activity since 1996. This dome growth continued until July 13, 2003 when the largest dome collapse took place. Three borehole strainmeters were operational during that activity and have provided excellent data associated with the collapse. Preliminary inspection of the data show that a dominant feature is a very long period (300 sec) tremor-like signal that began about 5 hours before the eruption. The amplitude of the signal generally increased with time, becoming a maximum about the time of the collapse and continued until well after the main collapse. This long period signal is also corresponds well with the short period amplitude signals recorded by the seismometers. The long period signals are presumably related to processes that provided the final contribution to the collapse. Additionally the strain records include much longer period disturbances that may provide constraints on the magma supply process.

V51J-0408 0830h POSTER

CALIPSO Borehole Instrumentation Project at Soufriere Hills Volcano, Montserrat, BWI: Data Acquisition, Telemetry, Integration, and Archival Systems

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The **CALIPSO** Project (Caribbean Andesite Lava Island-volcano Precision Seismo-geodetic Observatory) has greatly enhanced the monitoring and scientific infrastructure at the Soufriere Hills Volcano, Montserrat with the recent installation of an integrated array of borehole and surface geophysical instrumentation at four sites. Each site was designed to be sufficiently hardened to withstand extreme meteorological events (e.g. hurricanes) and only require minimum routine maintenance over an expected observatory lifespan of >30 y. The sensor package at each site includes: a single-component, very broad band, Sacks-Evertson strainmeter, a three-component seismometer (~Hz to 1 kHz), a Pinnacle Technologies series 5000 tiltmeter, and a surface Ashtech u-Z CGPS station with choke ring antenna, **SCIGN** mount and radome. This instrument package is similar to that envisioned by the Plate Boundary Observatory for deployment on EarthScope target volcanoes in western North America and thus the **CALIPSO** Project may be considered a prototype **PBO** installation with real field testing on a very active and dangerous volcano. Borehole sites were installed in series and data acquisition began immediately after the sensors were grouted into position at 200 m depth, with the first completed at Trants (5.8 km from dome) in 12-02, then Air Studios (5.2 km), Geralds (9.4 km), and Olveston (7.0 km) in 3-03. Analog data from the strainmeter (50 Hz sync) and seismometer (200 Hz) were initially digitized and locally archived using RefTek 72A-07 data acquisition systems (DAS) on loan from the PASSCAL instrument pool. Data were downloaded manually to a laptop approximately every month from initial installation until August 2003, when new systems were installed. Approximately 0.2 Tb of raw data in SEGY format have already been acquired and are currently archived at UARK for analysis by the CALIPSO science team. The July 12th dome collapse and vulcanian explosion events were recorded at 3 of the 4 sites. Steel reinforced, poured concrete crypts were constructed to house the surface instruments, data acquisition, telemetry components, and backup battery array with sufficient power to last 10 d without recharging. The central, cross-braced column of the crypt also functions as the monument for the CGPS antenna, which is coupled to a bedrock-grouted 1.5" steel pipe using a precision **SCIGN** level. In August 2003, the original temporary DAS were replaced with Quanterra Q330 six channel 24 bit systems equipped with PB14 digital packet balers, which can locally buffer up to 20 Gb of strain and seismic data in MSEED packets. All instruments are linked together via a cat 5 IP LAN and data are telemetered from each remote using a single FreeWave FGR-115RE ethernet radio bridge, and where necessary repeater, to the Montserrat Volcano Observatory. Here they are cached prior to transmission via a VPN to UARK for final archival. Detailed schematics and a photo archive are available online.

URL: http://comp.uark.edu/~mattioli/research/CALIPSO/Intro.html.

V51J-0409 0830h POSTER

Linking Surface Activity to the Deep Volcanic Plumbing System: the CALIPSO Borehole Observatory Project on Montserrat

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The prolonged and ongoing volcanic activity at Soufrière Hills Volcano (SHV), Montserrat, provides a rare chance for collecting multi-stream monitoring data in support of volcano research. Conventional surface geophysical instrumentation and detailed observational and geochemical data have enabled the development of a good understanding of surface and near-surface physical processes controlling eruptive style and intensity at SHV. However, the geophysical character and behavior of the deeper plumbing system, including magma storage area(s) and deep recharge processes, are not well understood. Developing better models for the deep system will assist in providing timely warning of large events or changes in eruptive style, and may also provide some clues as to the likely duration of the eruption. Installation of seismic and deformational monitoring instrumentation at depth enables a significant increase in signal to noise ratio so that smaller signals can be recorded and more distant sites (and thus deeper investigation depth) utilized. A variety of cycle-lengths have been noted during the eruption of SHV, and we hope that the new CALIPSO data stream will enable development of models in which cycles from a few hours to a few decades can be linked together in an integrated physical model. Cycle lengths of 7 to 14 weeks (depending on eruption rate and equating to the eruption of about 35 million cubic meters of magma) are likely to source from the shallower of the two upper crustal reservoirs indicated by geochemical evidence. The 30 to 35 year cycles (the fourth one of which marked the start of the current eruption) may relate to processes concerning input of basaltic magma to the deeper plumbing system. We also hope to document geophysical changes in the plumbing system induced by regional seismicity; many eastern Caribbean volcanoes (including SHV between 1933 and 1935 and in 1985) have demonstrated characteristics of unrest triggered or invigorated by regional tectonic earthquakes of Richter magnitude 5 and above. Events within the historical triggering threshold occur every few years; two such events have so far occurred since CALIPSO instrument installation (a Mw6.6 about 400km NE of Montserrat and a Mw5.7 about 150km NE of Montserrat). Both are at the lower end of historical triggering threshold parameters for magnitude and distance and neither produced measurable changes in macro-seismicity or ground deformation beneath SHV.

V51J-0410 0830h POSTER

CALIPSO Borehole Station Observations Before and During the July 2003 Montserrat Eruption

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The July 13 2003 eruption of the Soufriere Hills Volcano on the Island of Montserrat was recorded by the four borehole stations of the CALIPSO project. Each station was instrumented with a three-component seismometer, a Sacks-Evertson strainmeter, a tiltmeter, and a GPS recording unit. One borehole station was installed in December 2002 and the others in February 2003. The instruments were designed to record a full spectrum of earth movements from 500 Hz to yearly-type plate movements. The andesitic lava dome on Montserrat was growing without major collapse since July 2001. Several near surface seismic events that produced long period surface-wave seismic signals were recorded during the months before the July 2003 eruption. The anomalous sequence started about three days before the eruption with a large number of small seismic events with decreasing time interval between them until they blended together to form a volcanic tremor. Increased background seismic noise and large pyroclastic flows started about 18 hours before the eruption. The eruption itself was recorded by two seismometers and three strainmeters with ultra-long period signals dominating the strainmeter records. It is interesting to note that the peak short period signal recorded by the seismometer was about 10 minute before the peak of the ultra-long signal recorded by the strainmeter. A possible explanation for this delay is that the short-period seismometer recorded the large pyroclastic flows that expose the core of the dome, followed by a large magma movement and eruption as shown by the large ultra-long signal.

V51J-0411 0830h POSTER

Geomagnetic Change Associated With the Magma Intrusion at the Initial Stage of the 2000 Activity of Miyakejima, Central Japan

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A marked magnetic field change exceeding 200 nT was observed at the initial stage of the 2000 eruptive activity of Miyakejima Island, which is located 170 km to the south of Tokyo, Japan. The station recorded the magnetic change is one of the three continuous observations with three-component flux-gate type magnetometer in Miyakejima. The change began at 2100 LT on June 26 about 3 hours after the beginning of seismic swarm and crustal deformation in Miyakejima. A magma migration model obtained by Ueda et al. (2003, IUGG2003, Vol. A, p.553) from the crustal deformation data shows that magma was intruding very near the station at the time when the magnetic change was recorded. The crustal deformation has a strong correlation with the magnetic change. We evaluated a magnetic change due to the piezomagnetic effect from our magma migration model. The analysis indicates that the major part of the magnetic change can be interpreted quantitatively by the piezomagnetic effect of the magma intrusion. Other potential factors including thermal demagnetization, electorokinetic effect and movement of the magnetometer are unlikely to be the principal cause of it. The residual part that is not explained by the magma intrusion model may originate from piezomagnetic effect due to small cracks near the ground surface. Since the upper depth of the intruded magma is very shallow (<1km depth), small tensile cracks should be induced by the large stress changes around the upper bound of the magma. Such shallow small clacks, cause magnetic change especially near their edges, whose contribution to elastic deformation is small.

V51J-0412 0830h POSTER

Dike Intrusion Process of 2000 Miyakejima - Kozujima Event estimated from GPS measurements in Kozujima - Niijima Islands, central Japan

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Kozujima - Niijima Islands of Izu Volcano Islands are located about 180 km southeast of Tokyo, Japan. Although the last volcano eruptions in Kozujima and Niijima volcanoes are recorded more than 1000 year before, the ground deformation of 2-3 cm is detected at Kozujima - Niijima Islands by GPS measurements since 1996. On June 26, 2000, earthquake swarm and large ground deformation more than 20 cm are observed at Miyakejima volcano located 40 km east-southeastward of Kozu Island, and volcano eruption are continued

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since July 7. Remarkable earthquake swarm including five earthquakes more than M5 is stretching to Kozushima Island from Miyakejima Island. From the rapid ground deformation detected by continuous GPS measurements at Miyakejima Island on June 26, magma intrusion models of two or three dikes are discussed in the south and west part of Miyakejima volcano by Irwan et al.(2003) and Ueda et al.(2003). They also estimate dike intrusions are propagated from southern part of Miyakejima volcano to western part, and finally dike intrusion is stretching to 20 km distance toward Kozujima Island. From the ground deformation detected by GPS daily solution of Nation-wide dense GPS network (GEONET), some dike intrusion models are discussed. Ito et al.(2002) estimate the huge dike intrusion with length of about 20 km and volume of 1 km3 in the sea area between the Miyake Island and Kozu Island. (And) Nishimura et al.(2001) introduce not only dike but also aseismic creep source to explain the deformation in Shikinejima. Yamaoka et al.(2002) discuss the dike and spherical deflation source under the dike, because of no evidence supported large aseismic creep. They indicate a dike and spherical deflation source model is as good as dike and creep source model. In case of dike and creep, magma supply is only from the chamber under the Miyakejima volcano. In dike and spherical deflation source model, magma supply is from under Miyakejima volcano and under the dike. Furuya et al.(2003) discuss the gravity change of Miyakejima and they conclude that the magma supply from the chamber under Miyakejima volcano is too small to explain the dike intrusion. In order to discuss the local ground deformation, Nagoya University additionally operates the local GPS network of single frequency receivers at seven sites in Kozujima, Shikineshima and Niijima. Form the vertical deformation detected on local GPS network, northward tilting is observed in Kozujima. We used Genetic Algorithm (GA) for search the model parameter of dike intrusion and fault. GA is an attractive global search tool suitable for the irregular, multimodal fitness functions typically observed in nonlinear optimization problems. We discuss mechanism of Miyakejima - Kozujima event in detail using data of 20 GPS sites near field by GA. The results suggest that magma intrusion system of the dike between Miyakejima and Kozujima changes on August 18 when a large volcano eruption occurred. Until August 18 the activity of creep fault is high and after then deflation at the point source just under the dike is active.

V51J-0413 0830h POSTER

Was Miyakejima undergoing subsidence before the 2000 caldera collapse? JERS1 InSAR results: 1992-1998

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Miyakejima volcano is a basaltic strato volcano island on the eastern edge of the Philippine Sea Plate, and was undergoing a number of eruption activities over the past centuries. In July-August 2000, the Miyakejima volcano underwent a caldera collapse, prompting many modern geodetic and geophysical measurements (e.g., Geshi *et al.* 2002; Furuya *et al.* 2003). The observation results on the pre-caldera-collapse stages are, however, limitted. Were there any precursory secular subsidence before the collapse? Though Miyazaki (1990) reported a secular subsidence at the Miyakejima, using leveling technique, there are no documented reports, to my knowledge, which employed radar interferometry to examine the ground displacements at Miyakejima. Here I will report on the results derived from the radar interferometry at Miyakejima volcano. I chose JERS-1 data (L-band HH) for the analysis, so that I could get rid of the loss of coherence; most of the Miyakejima is covered with vegetation. To remove the topographic fringes as well as to re-estimate the spatial baseline data (Rosen *et al.* 1996), I employed 10-meter resolution digital elevation map derived by Geographical Survey Institute, Japan. I could generate 24 differential interferograms at the time of writing this text. However, I do not yet recognize any significant "signals" that can be discriminated with the atmospheric "noise". There appears to be no specific subsidence pattern, which are detected in a number of other volcanos in the world (e.g., Lu *et al.* 2002; Yarai *et al.* 2002; Okuyama *et al.* 2002). I am going to show a stacked interferogram like that in Fujiwara *et al.* (1998) and to examine the existence of volcanic signals.

V51J-0414 0830h POSTER

Crustal Deformation of Iwojima Volcano Detected by SAR Interferometry and GPS Observations

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Iwojima volcano is located in the Izu-Bonin islands arc, about 1250 km south of Tokyo. Small phreatic eruptions occurred more than 15 times in Iwojima volcano since 1889. Crustal deformation has occurred on a remarkable scale at the volcano. We tried to comprehend the deformation field of Iwojima volcano by SAR interferometry and campaign GPS observation. We processed 20 different pairs of JERS-1 SAR data spanning 1992 to 1998. The concentric circular fringes around Motoyama, northeastern Iwojima Island, can be seen at most interferograms. The line of sight (LOS) displacement at the center of Motoyama was increasing constantly. In Chidoriga-hara, the southwestern Iwojima Island, the fringes patterns of the interferograms were not constant but changed episodically. We have started the GPS campaign observation since August 2002. The observation stations have been observed at 3 months interval. The shrinking of Motoyama and the inflation of Chidoriga-hara were detected by GPS observations. The largest horizontal displacement of above 7cm was observed near the Chidoriga-hara during August and November 2002. The stations around Motoyama have displaced constantly. In contrast, the speed of displacements around Chidoriga-hara is not constant but decreasing with time. These features of deformation appeared by GPS campaign observations is similar to interferograms from JERS-1 InSAR. We constructed a preliminary model for the deformation field of Iwojima. The deformation field can be explained by two sources, a deflation source beneath the center of Motoyama and a tensile fault beneath Chidoriga-hara. The location and the volume change rate of the deflation source estimated from GPS observations (-$0.7\times10^7 m^3$/year, 3.0km depth) is near the deflation source which are estimated from JERS-1 InSAR (-0.4-$1.5\times10^7 m^3$/year, 1.5-3.0km depth).

V51K MCC: 3006 Friday 1020h

Light Element Geochemistry: Insights Into High-Temperature Processes II

Presiding: **W Bach,** Woods Hole Oceanographic Institution**; T Elliott,** University of Bristol

V51K-01 1020h

Ab initio molecular orbital calculations for boron isotope fractionations on boron acids and borates

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Based on the studies of Hemming and Hanson (1992) and Palmer et al. (1987), the stable B isotopic composition (d11B) of carbonate has been used as a pH-indicator to reconstruct the paleo-pH value of seawater and the paleo-CO2 in the atmosphere (e.g. Palmer and Pearson, 2003; Sanyal et al., 2000; etc.). This promising approach is based on the basic isotope exchange reaction between B(OH)3 and B(OH)4-:
10B(OH)3 + 11B(OH)4- – 11B(OH)3 + 10B(OH) (1) The isotopic fractionation coefficient K for the above reaction is hence very important for building the relation between pH and d11B composition. However, for a long time, there has been only one calculated value given by Kakihana et al., (1977), which K=1.0194 at 25°C. Unfortunately, Kakihana et al. used a theoretical method to calculate this value without specifying its details. Hence we indeed don't know how accurate this value is. Recently, Oi (2000, 2001) has calculated the K value again by using the ab initio molecular method and a simple scaling method. His calculated K value is 1.0260. Compared to 1.0194 provided by Kakihana et al., this difference already can cause a change in predicted pH of at least 0.5 pH unit. Oi (2000) also suggested a wrong approximation method for the K values for polyboric acids and polyborates. Hence we think a careful re-calculating on this issue is needed. We calculate the isotopic fractionation K value by different approaches: the water-cluster and the simple scale factor method Oi has used. We also extend the calculations for polyborates and polyboric acids, which are important in some cases. Our results show the K value should be about 1.025 to 1.027 based on our water-cluster model. Our calculations on different temperatures and on 4-coordinated B in silicates (such as the BO4(Si(OH)3)4- cluster) can let us easily explain many experimental results.

V51K-02 1035h INVITED

Fractionation of Boron (and Lithium) Between Hydrous Fluid and Silicate Melt: Diffusion, Contamination, and Orphaned Experiments

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We have measured the isotopic fractionation of boron between hydrous fluid and basaltic and rhyolitic melt using boron rich (approx. 2000 ppm B) anhydrous starting glasses. The results showed that heavy boron was preferentially partitioned into the fluid, even at high temperatures. We are now attempting reversal experiments by equilibrating B-rich hydrous fluid with B-poor silicate melts. A rhyolitic run product most recently recovered (100MPa, 900C, 48 hours) was mounted in epoxy and analyzed by SIMS for H, Li, B, and B isotopes. At the fluid-melt interface, boron concentrations were influenced by B-rich phases on the meniscus presumably quenched from the fluid. At distances of 10 to 100 microns from this interface the boron concentration dropped from approx. 600 ppm to 9 ppm, respectively (the initial B content of the rhyolite) while the H content was constant (3.2 wt.%) throughout. The boron isotope ratios become lighter with decreasing B content. This experiment 1) shows that the diffusion of boron is slow (<1E-13m2/s), but is >10000x faster than in anhydrous systems, and 2) confirms that hydrous silicate liquids concentrate the light isotope of B compared to hydrous fluid. We have also examined older experiments (performed for other purposes) to see if the boron and/or lithium contents and isotope ratios of these melts (equilibrated with hydrous fluids) can help us understand the high-temperature behavior of these light elements. For example, our earlier experiments measuring boron isotope fractionation between Li-rich (3400 ppm Li) macusanite rhyolite and hydrous fluid also show significant Li loss to the fluid allowing the determination of a fluid melt partition coefficient (D(Li) fl/melt) of 1.7 at 500 MPa. However, experiments on MORB glass containing initially 6 ppm Li reveal a gain of 1000 ppm Li during the run. Similar contamination of piston cylinder and internally heated experiments have been observed for boron as well as lithium. For example, in a study of D and H diffusion in rhyolite melt by (1), a lithium profile was also observed, with an implied diffusion coefficient near 1E-11m2/s. In contrast to these experiments, the above study on rhyolite showed a slight decrease in Li content in the melt implying a D(Li) fl/melt of 0.5 at 100 MPa. This Au capsule was cleaned in HF followed by sonication in a degreasing solvent, thereby minimizing light element contamination. Capsules from earlier experiments (Au, AuPd, AgPd) that were not degreased all show extreme light element contamination. Complementary experiments on boron fractionation between andesite and hydrous fluid are in progress. (1) Stanton, T. (1990) PhD Thesis, ASU.

V51K-03 1050h INVITED

Stable Chlorine Isotopes in Ocean Crust Processes

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The study of natural variations of Cl isotopic composition in ocean crustal rocks has large potential to further our understanding of geochemical cycling of volatiles and elements soluble in saline aqueous solutions. Studies of oceanic basalt suites to date confirm that Cl abundances are highly sensitive to the addition of saline components - either from addition of subduction-related volatile fluxes in back-arc basins