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Highly explosive eruptions from Masaya Caldera Complex (central Nicaragua) during the past 6000 years: Stratigraphy and hazard aspects

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The very active Masaya Caldera Complex in Nicaragua poses major hazards to the densely populated capital, the large Managua area. The volcanic hazards are due to the frequency of eruptions, the large erupted volumes and the high velocity ground transport during the common phreatomagmatic eruptions. Over the last 6000 years, at least four main highly explosive basaltic plinian, subplinian and phreatoplinian alternated with phreatomagmatic eruptions. A particularly vigorous phreatomagmatic eruption was related to the formation of the caldera. We distinguish five main Holocene pyroclastic deposits: (1) San Antonio Tephra (SAT, ca. 6000 years), (2) La Concepción Tephra (LCT), (3) Masaya Triple Layer (MTL), (4) Masaya Tuff (MT, ca. 1000 years BP) and (5) Ticuantepe Lapilli (TIL). The lower fallout sequence of SAT alternates with phreatomagmatic surge deposits and culminated in a major fallout lapilli layer. The LCT is a succession of 8 main well-sorted, scoria lapilli to fallout coarse ash layers, intercalated with phreatomagmatic fallout and surge deposits, south of the caldera. The MTL resembles the LCT, is composed of 7 major beds of well-sorted lapilli to coarse ash, and is separated by 4 major and several minor phreatomagmatic tuff layers, dispersed to the NW, in direction of Managua city. 14C dating yielded an age of 2120 years BP for the MTL. The ca. 1000 year old MT is a partly indurated, poorly-sorted major deposit that extends to a distance of at least 35 km, covering much of the ground of the present Managua area. Poor sorting, high ash content, abundance of dunes and cross-bedding as well as the radial distribution around the caldera indicate an origin by high velocity pyroclastic surge. The end of the MT eruption is

marked by well-sorted, fallout lapilli, the TIL. Tephra volumes ranging from 0.2 km3 to 3.9 km3 indicate 1011 to 1012 kg of magma discharged during the violent eruptions reaching magnitudes between 4.3 and 5.9, and Volcanic Explosivity Indices (VEI) of 3 to 4. The highly energetic phreatomagmatic eruptions of the Masaya Tuff produced base surges that radiated directly from the vent to a runout distance of 20 km and were able to surmount topographic barriers several hundred meters high. The geologic record shows no precursory activity that may have heralded their appearance. The eruption itself started with a blast resulting a thin proximal to medial basal layer, rich in lithic fragments and quenched vitric lapilli. The sudden occurrence and rapid spreading of surges such as those of MT are instantaneous highly destructive events. Even the subplinian to plinian, mainly fallout-producing eruptions of Masaya were repeatedly interrupted by collapse of the eruption column and production of pyroclastic surges, although of much lower energy and lateral runout compared to the MT. The central western region of Nicaragua is highly vulnerable because it is the area of highest population density of the country. The main cities Managua, Granada and Masaya, the International Airport, the Panamerican Highway, government buildings and embassies, factories, and the telephone, water and energy supply companies are all concentrated in this area. Recurrence of major eruptions such as those described are likely to occur again in the future, necessitating a wide range of mitigation measures and monitoring activities to prevent a major disaster in the heart of the country.