Introduction. Calderas are defined as large, more or less circular, volcanic collapse depressions with diameters considerably larger than any included vent [1,2] resulting from collapse into partially drained near-surface magma chamber [2]. They have been defined as having diameters >1 km [3], with smaller depressions being called craters. Usage of term caldera, includes features described as “cauldrons”, which represent a variably deeper erosional level of the same fundamental structures [4, 5]. Our goal here is to overview types of calderas on Earth, mechanisms and models of their formation for following comparison with venusian calderas [6].

Methods. We summarized aspects of calderas formation using models of caldera formation [5,7], maps and description of typical calderas [8-10], and overviews of calderas formation and classification [2,5,7].

Caldera geometry, structural elements. Structural and morphologic elements of a simplified caldera model include [5,7] (Fig. 1-3): topographic rim, inner topographic wall, bounding faults (if present), structural caldera floor, intracaldera fill (ash-flow tuff, lava flows, and landslide debris from caldera walls), and the underlying magma chamber or solidified pluton.

Classification of calderas. There are few classifications of calderas (genetical, chemical, tectonic). We took one of them by [2] with some modification and simplification according to Vic Camp volcanology website [11]. Three morphological classes are important on the Earth: basaltic shield volcano calderas, Crater-lake type of calderas, and ash flow calderas.

Basaltic shield volcano calderas. The summit regions of many active shield volcanoes are marked by calderas (Fig. 1). It is generally believed that shield caldera formation is due principally to drainage of magma rather than explosive removal of it from a magma chamber. Instead, they subside in increments to produce a nested structure of pits and terraces. Basaltic calderas like these are gradually enlarged by episodic collapse, due to the extraction of lava from shallow-level magma chambers underlying the summit areas. Shield calderas form in basaltic volcanoes, with tholeiites being typical rock types for both large and small shields, sometimes in aluminous basalts and basaltic andesites [2,12].

Crater-lake type of calderas (Fig. 2) is generated after the main phase of a Plinian eruption, during collapse of a stratovolcano (Mt. Mazama in Crater-lake caldera) into the void of the underlying, depleted magma chamber. Although the waning phase of a Plinian eruption is often associated with the generation of pyroclastic flows, piston-like collapse of the volcanic edifice can generate the additional eruption of voluminous (0.1-100 km³), pumice-dominated sheet flows along ring fractures surrounding the collapsing mass. These sheet flows form thick deposits of ignimbrite, the hallmark of both Crater-lake type and ash flow calderas. Caldera formation has occurred two or more times in many stratovolcanoes; many stratovolcanoes have a caldera as their final evolutionary stage. Stratocone calderas usually form in volcanoes made of basaltic andesite or andesite, with occasional basaltic, trachytic, and phonolitic structures [13]. Ejecta associated with stratocone caldera formation is typically dacitic to rhyolitic.

Ash flow calderas result from collapse following the eruption of extremely large (100-1000 km³) volumes of dacitic to rhyolitic ash flows (Fig. 3). These calderas are the largest, and most were not formed on existing massive volcanoes. Ash flow calderas also dominantly erupt dacite to rhyolitic ignimbrite or alcalic rocks. Many calderas larger than about 20 km diameter have resurgent centers, apparently updomed during or by the refilling of the underlying magma chamber [2,14] (Fig. 3). With diameters ranging from 15 to 100 km, resurgent calderas dwarf those of the Crater-Lake type. They are similar to Crater-Lake type calderas in that they are also generated by crustal collapse above shallow magma chambers. Resurgent calderas, however, are too
large to have been associated with a Crater-Lake type central volcano. Apart from their large size, the definitive feature of resurgent calderas is a broad topographic depression with a central elevated mass resulting from post-collapse upheaval of the caldera floor. The caldera floor is typically filled with rhyolitic lavas, obsidian flows, and domes; the uplifted centers often contain elongate rifts (grabens) along their crests (Fig. 3).

Fig. 3. Geological map of Yellowstone caldera (Idaho, Wyoming, Montana) by [10] overlain on shaded relief map. Resurgent domes are located in NE and SW parts of caldera.

Caldera subsidence processes. Many calderas have such varied transitional geometries and structures that subclassification into discrete types seems less useful than relating subsidence geometry and resulting structures to a few geometrically simplified end-members [5,7] (Fig. 4). Small calderas (<3-5 km diameter) commonly have funnel geometry (e) because of dominant enlargement by slumping into an areally restricted vent. Many larger calderas dominantly involve plate (piston) collapse (a) of a coherent floor, bounded by steeply dipping ring faults; they are inferred to reflect voluminous eruptions from large shallow magma chambers. Trap-door subsidence (c), bounded by an incomplete ring fault and by a hinged segment, reflect early downsagging and incipient plate collapse related to smaller eruptions, an asymmetrical magma chamber, or regional tectonic influences. Deep magma chambers or small eruptive volumes may favor downsag subsidence (d) without large bounding faults, although the appearance of downsag can be generated by younger volcanic units draped over a pre-existing caldera or structural basin. Pervasively brecciated chaotic disruption (b) of subsiding caldera floor is uncommon, at least at calderas more than a few kilometres across. Interpreting caldera structures in terms of a continuum of subsidence styles, rather than as end-member types, can clarify relations between eruptive and structural processes in comparison with size of the eruption and geometry of the cogenetic magma chamber. The size of magma chambers and volume of ash-flow eruptions strongly influence both caldera-subsidence processes and the lithologies of exposed intracaldera volcanic fill.

Evolution. Five principal stages can be recognized [4]: 1) precursor; 2) caldera collapse; 3) early post-collapse volcanism; 4) major ring-fracture volcanism; and 5) hydrothermal activity. Development can be terminated at any stage; stages can also be repeated. Resurgent doming can occur during stage 3 or later; doming can also be enhanced by reactivation of cauldron structures by postvolcanic basin and range faulting.

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