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Onset and early evolution of submarine-to-emergent explosive activity during the Surtsey eruptions, Iceland, 1963-1967

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The formation of the oceanic island Surtsey in the shallow ocean off the south coast of Iceland in 1963-1967 remains one of the best-studied examples of basaltic emergent volcanism to date. Cycles of the phreatomagmatic explosive activity occurred several times during the eruptions: (1) At the onset of the eruption - eruption of Surtur crater, November 1963-January 1964; (2) The submarine eruption of Surtla - December 1963; (3) the formation of the parasitic cone of Surtungur - January-April 1964; (4) formation of the temporary island of Syrtlingur - May-October 1965; and (5) the formation of the temporary island of Jólnir - December 1965-August 1966. Explosive activities at these vents are well-documented and preserved in photographic records and reports. The first submarine volcanic activity was detected on 14th of November 1963 where ocean depth was 130 m prior to the eruption. The onset time of the submarine eruption was not resolved in contemporary records. Birth of the submarine eruption at the seafloor can be detected by investigation of tremor signals or any unusual 0seismic activity at nearby seismograms.
Seismic records from the time of the Surtsey eruption are available from two permanent seismic stations in south Iceland: Reykjavík in southwest Iceland and Kirkjubæjarklaustur in southeast Iceland. These records have now been re-analyzed. Any potential eruption signals are drowned by microseisms at the Reykjavík station while at the Kirkjubæjarklaustur station eruption tremor signals appeared before the first explosive eruption had broken through the sea floor. Earthquake activity related to the beginning of the eruption was weak, hardly detectable by the existing seismograph stations.
These observations indicate that the actual start of the submarine eruption occurred no later than on 13th of November, with eruption tremors recorded 18-24 hours before the first visual observation of eruption from a fishing boat in the early morning of the 14th of November. Similar tremors were also detected during other four explosive phases. The potential of seismic records to detect the onset of eruptions is demonstrated through these results. Based on the shreds of evidence for the onset time and the visual observations, maps and descriptions, we derive the early growth history of Surtsey. When combined with bathymetric data prior to the eruption, we obtain constraints on the rate of submarine cone buildup. This places constraints on the eruption rate in these early submarine-to-emergent phases of the eruption. Early results indicate that the maximum mass eruption rate in the beginning phase was relatively modest, below 1,000,000 kg/s.