Soil Dynamics and Earthquake Engineering 29 (2009) 1073–1083

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

The M_w6.3 Ölfus earthquake at 15:45 UTC on 29 May 2008 in South Iceland: ICEARRAY strong-motion recordings

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ARTICLE INFO

Article history:
Received 2 October 2008
Received in revised form
15 December 2008
Accepted 16 December 2008

Keywords:
ICEARRAY
Strong-motion array
Near-fault
Accelerogram
Peak ground acceleration
Response spectrum
Earthquake
Iceland

ABSTRACT

At 15:45 UTC on 29 May 2008 a M_w6.3 earthquake occurred in the western part of the South Iceland Seismic Zone (SISZ). Preliminary results indicate that the first motion originated approximately 6.5 km east–southeast of the town of Hveragerdi on what aftershocks appear to identify as an almost 10 km long north–south trending fault. However, most aftershocks outlined another almost 20 km long north–south trending fault less than 2 km from the town of Hveragerdi, which happens to be the location of the recently deployed ICEARRAY, the first small-aperture strong-motion array in Iceland. The ICEARRAY produced high-quality recordings on 11 stations over an aperture of ~1.9 km and a ~50 m minimum interstation distance. The recordings are characterized by strong motion of short duration and high intensity, manifested by the geometric mean of horizontal peak ground acceleration ranging between 0.44 and 0.87 g. Moreover, a prominent long-period near-fault velocity pulse is observed both along the strike-normal and strike-parallel directions. Its apparently repetitive behavior may reflect the complex source effects of the two-fault system. The linear response spectra of the ICEARRAY data indicate that the long-period energy of the velocity pulse seen along the strike-normal direction is not present in the strike-parallel direction. However, the long-period spectral energy seen along the strike-parallel direction is most likely caused by permanent tectonic displacement. Along the strike-normal direction, the Eurocode 8 "Type 2" design spectrum combined with a design spectrum for near-fault motion with distinct pulses appears to capture well the overall spectral composition of the ICEARRAY response spectra. We believe that these globally unique ICEARRAY recordings are of importance to the fields of earthquake engineering and engineering seismology.

1. Introduction

Iceland straddles the Mid-Atlantic Ridge, the diverging boundary of the North American and Eurasian plates. On land, the boundary is categorized by zones of active tectonic extensional and transform motion, respectively. The extensional zones define Iceland's active volcanic belts while the transform zones define the regions of greatest earthquake hazard, the South Iceland Seismic Zone (SISZ) in the south and the Tjörnes Fracture Zone (TFZ) in the north, as indicated in Fig. 1. In contrast to the TFZ, which is largely offshore, the SISZ is the largest agricultural area in Iceland and among its most densely populated regions. The potential of the SISZ of producing destructive earthquakes as large as M_w7 [1] makes it the region of greatest seismic risk in Iceland [2]. Since 1896, when a sequence of six moderate-to-strong earthquakes ruptured the SISZ in a period of two weeks, four damaging earthquakes have occurred in different sections of SISZ: the 6 May 1912 M_w7 earthquake in the easternmost part of the SISZ; and in the central part the 17 June 2000 M_w6.5 and the 21 June 2000 M_w6.4 earthquakes (CMT, [3]). The fourth destructive earthquake to take place in the SISZ was the 29 May 2008 M_w6.3 (according to CMT and INGV, [4]). It ruptured the westernmost part of the SISZ, the densely populated Ölfus region between the towns of Hveragerdi and Selfoss (see Fig. 1). This earthquake caused widespread damage in the area [5] and was well recorded on the Icelandic strong-motion network (IceSMN, [6]) and the new Icelandic small-aperture strong-motion array (ICEARRAY) in the town of Hveragerdi [7]. Deployed only seven months before the earthquake, ICEARRAY's timing and location has proven to be most fortunate as it has produced a globally unique dataset of extreme near-fault strong motion, the recordings of which exhibit significant long-period components and large peak ground accelerations (PGAs). The current study presents the ICEARRAY recordings of strong motion during the 29 May 2008 M_w6.3 earthquake and describes their key characteristics.

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doi:10.1016/j.soildyn.2008.12.006

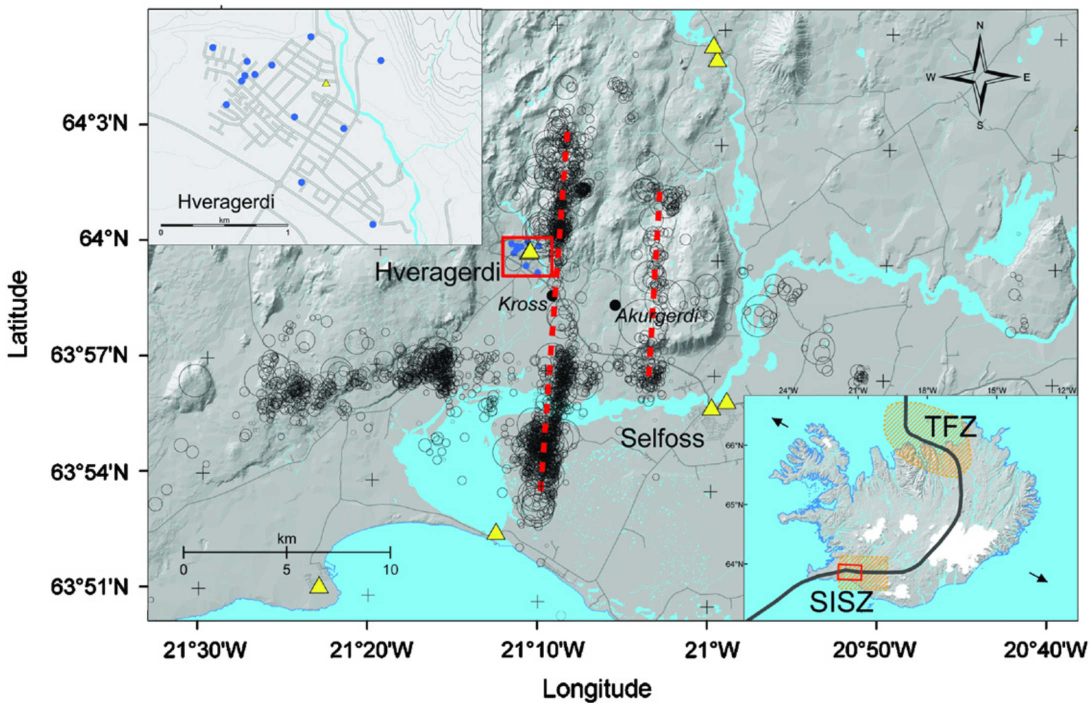

Fig. 1. North–south trending alignment of the seismicity distribution for the period of 29 May to 29 June, 2008, (circles, [8]) in south–west Iceland indicates the location of the causative faults (approximated by the dashed lines) of the 15:45 UTC 29 May 2008 earthquake. The triangles are the closest recording sites of the Icelandic strong-motion network. The inset picture bottom right shows Iceland with respect to the rift axis of the Mid-Atlantic Ridge (line), the Tjörnes Fracture Zone (TFZ) in the north and South Iceland Seismic Zone (SISZ) in the south indicated by the shaded areas. The solid rectangle within the shaded area indicates the one shown in the main picture. The solid rectangle in the main picture indicates the area of the town of Hveragerdi shown at top left, depicting the locations of the recording stations of the ICEARRAY (dots) against the town's street layout.

2. The Icelandic strong-motion array

The ICEARRAY is the first small-aperture strong-motion array in Iceland. Its purpose is the monitoring of significant earthquakes in the SISZ, establishing quantitative estimates of the spatial variability of their strong ground motion, and shedding light on earthquake source processes. ICEARRAY is located in the town of Hveragerdi, in the Ölfus District of South Iceland, due to its proximity to destructive earthquakes in the past, the relatively high population density of the western SISZ and for collocating the array with engineering structures [7]. Moreover, numerous lifeline systems such as bridges, cross-country pipelines, electric transmission systems, earthfill dams, etc. are located in the region. The spatial variability of strong motion is an important factor in the earthquake resistant design of structures of such considerable horizontal extent. The ICEARRAY, designed in order to maximise its versatility and usefulness for seismological and earthquake engineering applications, consists of 14 stations in an area of $\sim$1.23 km^2 inside the town of Hveragerdi. The array has an aperture of $\sim$1.9 km and a minimum interstation distance of $\sim$50 m [7]. The ICEARRAY geometry is shown in Fig. 1 (top left) where the stations are represented by dots and a triangle, the latter indicating a recording station commonly shared with the IceSMN. For completeness, the list of ICEARRAY stations is given in Table 1. In all cases the instruments are located on the ground floor (or in the basement) of single-storey concrete buildings with the exception of station IS609 being located in a double-storey concrete building. Each ICEARRAY station is equipped with a single CUSP–3Clp strong-motion accelerograph unit manufactured by Canterbury Seismic Instruments Ltd. The sensor is a triaxial low-noise ($\sim$70 μg rms) microelectromechanical (MEM) accelerometer that possesses a high-dynamic range (±2.5 g) and a wide frequency passband (0–80 Hz at 200 Hz sampling frequency). Running in triggered mode, a GPS timing system assigns each sample point an absolute time stamp and the datafiles are saved to a solid state memory disc. After saving, being equipped with uninterrupted Internet connectivity via a wireless GPRS data connection, the unit uploads the data to a central CUSP-HUB smart network manager, located at the Earthquake Engineering Research Centre. Thus, the data are backed up and available for analysis a few minutes after an earthquake. Moreover, the CUSP–HUB runs a dedicated "common-triggering system" [9] that continuously monitors the ICEARRAY and maximizes its efficiency in recording earthquake events while at the same time minimizes the analyst's efforts in reviewing data.

Table 1
Recording stations of the ICEARRAY strong-motion array.

Station ID	Station name	Lat. (°N)	Lon. (°E)
IS601	Heidarbrun 51	63.99265	−21.17764
IS602	Kambahraun 39	64.00473	−21.20429
IS603	Dynskogar 3	64.00289	−21.19740
IS604	Borgarhraun 12	64.00243	−21.19951
IS605	Borgarhraun 8	64.00282	−21.19901
IS606	Kambahraun 18	64.00384	−21.19871
IS607	Arnarheidi 26	64.00074	−21.20179
IS608	Sunnumork 2 (E)	63.99538	−21.18925
IS688	Sunnumork 2 (W)	63.99538	−21.18925
IS609	Dvalarheimilid As	64.00252	−21.18591
IS610	Reykir	64.00424	−21.17722
IS611	Heidmork 31	64.00002	−21.19075
IS612	Reykjamork 17	63.99931	−21.18282
IS613	Laufskogar 39	64.00572	−21.18862
IS614	Dynskogar 26	64.00360	−21.19470