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Mt. Hudson revisited 12 years on: what are the long-term health effects from fine ash produced during the 1991 eruption?

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Cerro Hudson, Patagonian Andes

Cerro Hudson is a historically active stratovolcano. It is the southernmost volcano in the Chilean Andes, and is related to the subduction of the Nazca plate under the South American plate. It attains an elevation 1905 m asl. and has an aerial extent of 300 km². The Hudson volcanic complex consists of a 10×7 km caldera (fig. 1) with several vents covered by Patagonian glacier ice (Naranjo et al. 1993).

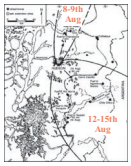
Figure 1 *The ice-covered caldera of Cerro Hudson, Chile*

Historical Eruptions

An eruption around 5000 yr B.P. (VEI 6-7) wiped out all existence of early man living in Central Patagonia at that time (*Los Toldos archaeological site* - Cardich 1985).

On August 12th 1971, Hudson erupted (VEI 3) producing a plinian column 7-14 km high that dispersed tephra over an area of 60 km², causing significant crop and cattle damage. The volcano erupted again on 23rd August 1971, sending a plume to ~6 km. Glaciers atop the volcano melted and produced lahars that claimed the lives of many people, much livestock and destroyed 80% of arable land in the Huemules valley (Smithsonian Global Volcanism Program; Bitschene 1995).

August 1991 eruption



Cerro Hudson erupted most recently in two separate, partially sub-glacial phreato-plinian cycles on August 8th (starting at 18:20 CLT) and on August 12th 1991 (starting at 12:00 CLT) (fig. 2). The first cycle was mainly basaltic, erupting tephra consisting of trachyandesitic and sideromelane glasses. The second cycle was characterised by the paroxysmal eruption of trachyandesitic and ryhodacitic material (Bitschene & Fernandez 1995).

The August 8-9th eruption produced an ash column 7 to 10 km high (fig. 3), which subsequently rose to 12 km. Ash was dispersed by winds to the NNE (fig. 2). Thunder, lightening, black fall-out ash and a sulphurous odour were noted at Pto. Chacabuco and Pto. Aisen (Chile) about 30 minutes after the onset of the eruption. The eruption melted the capping glacier and produced lahars that travelled down the Huemules Valley (which lies several kilometres to the West). These flows inundated the valley with material, transporting metre sized blocks up to 20 km from the source.

Figure 2 (left) *Distribution of tephra deposits from the August 8-9th and August 12-15th eruptions of Cerro Hudson, Chile (José Naranjo, BGVN 16:07)*

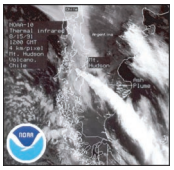


Figure 3 (above left) *Eruption cloud at 19:30 CLT on the 8th August 1991 from Coyhaique, Chile;* ***Figure 4 (above centre)*** *Thermal Infrared Image (TIR) of the eruption cloud at 1200 GMT (CLT-4) on 15th August 1991 of Cerro Hudson, Chile;* ***Figure 5 (above right)*** *Isopach thickness map of the 12-15th August 1991 deposit from the eruption of Cerro Hudson (from Scasso et al. 1994)*

In one of the largest eruptions of the century, Hudson erupted again between August 12-15th producing a column 18 km high. Ash was deposited up to 1,000 km SE on the Falkland islands (fig. 4) and covered a total area of ~80 000 km² (fig. 5 & 6). DRE (dense rock equivalent) tephra volume estimates range between 2 and 6 km³: >1 km³ was deposited in Chile, around 2 km³ in Argentina, and 2 km³ may have fallen in the Atlantic Ocean or been lost to the atmosphere. Satellite data showed that the eruption produced a large SO_2-rich cloud, estimated to contain 1.5 megatons of SO_2 on 16 August, which was transported twice around the globe in 2 weeks (BGVN 16:08).

Reworking of deposits

Major reworking of ash deposits in Argentina by strong winds led to several false reports of renewed activity at Hudson in following weeks. Ash was re-suspended and distributed N to Comodoro Rivadavia (2 mm at 400 km E of Hudson), and was also reported S to Río Gallegos (700 km SSE) *(see fig. 6 for location map)*. In early September, GOES satellite images detected ash clouds, probably below 3 km, carried by ground-level winds at 55-65 km/hr: these clouds extended from near the volcano to over the Atlantic ocean. The densest part of the clouds appeared to be ~250 km SE of the volcano, about halfway to the Argentine coast. Poor visibility down to only a few hundred meters, was reported at Puerto Deseado and Puerto San Julián. These suspended dust veils impacted airline traffic for many months after the eruption.

Provincia de Santa Cruz

Figure 7a *Rio Ibáñez valley (Chile) in August 2000. Tephra fall-out from the 1991 Hudson eruption "clogged the river, causing it to spread out over more than a mile in width, and the combination of water and toxic ash content killed thousands of trees and the fish. The ash plume extended to the watersheds for Lago General Carrera (Chile), and caused some silting in on a portion of the lake."*

Figure 7b *Area adjacent to Rio Ibáñez valley (Chile) in August 2000. The top of the fence posts were about four feet above the ground prior to the 1991 Hudson eruption.*

Images and witness report can be found at:

http://www.geocities.com/foraster/aug00_8.html

Figure 6 (left) *Map of the Provincia de Santa Cruz (Argentina) which was inundated with ash fall-out from the 1991 eruption of Cerro Hudson, Chile.*

Table 1 *Population statistics for the Provincia de Santa Cruz*

District	Area km²	1991 Population	1991 %	1991 Density people/km²	2001 Population	2001 %	2001 Density people/km²
Total	**243,943**	**159,839**		**0.7**	**196,958**		**0.8**
Corpen Aike	26,350	7,045	4	0.3	7,942	4	0.3
Deseado	63,784	56,879	36	0.9	72,953	37	1.1
Güer Aike	33,841	79,032	49	2.3	92,878	47	2.7
Lago Argentino	37,292	3,940	2	0.1	7,500	4	0.2
Lago Buenos Aires	28,609	4,975	3	0.2	6,223	3	0.2
Magallanes	19,805	5,314	3	0.3	6,536	3	0.3
Río Chico	34,262	2,654	2	0.1	2,926	1	0.1

Source: INDEC. Censo Nacional de Población y Vivienda 1991 y Censo Nacional de Población, Hogares y Viviendas 2001 e Instituto Geográfico Militar.

Immediate health effects

- People living in the upper Rio Ibanez (figs. 7a & 7b) and Huemules valley (Chile) suffered nausea and headaches from sulphurous emissions due to fumerolic activity.
- Local hospitals in Chile Chico (Chile), and Los Antiguous and Perito Moreno (Argentina) reported a slight increase in nervous distress, allergic reactions and asthmatic problems from the fine 'dust', and eye irritation including occasional conjunctivitis.
- Breathing difficulties reported in areas where information was not disseminated quickly about avoiding contact with the ash.
- Prolonged contact of ash with skin resulted in burning.
- Psychosis from heavy ash falls, day-long darkness and lack of information.
- No fatalities were reported during or after tephra fall-out.

Other consequences...

- 600 people evacuated from Perito Moreno and Los Antiguos: most returned shortly after.
- Adobe buildings in Bajo Caracoles (200 km SE of Hudson) damaged by earthquakes.
- Building roofs collapsed in proximal areas from water and ash loading.
- Acid rain burnt paint on house roofs in Gob. Gregores (about 350 km SE of Hudson).

Effect on livestock populations

- 500 000-600 000 sheep died following the eruption.
- Starvation: ash covered up grass and filled watering holes.
- Gastrointestinal problems from ingestion of ash that formed concretions in the stomach.
- Ash accumulation in fleeces increased overall weight by several kilograms, resulting in exhaustion and starvation.
- Eye complaints causing disorientation and blindness.
- Wear down of teeth by abrasion of volcanic ash.
- Similar effects were also observed in autochthonous wildlife, especially birds: complete desolation in heavily affected areas.

Effect on potable water supplies

- Water systems in Chile Chico, Los Antiguous and Perito Moreno were clogged with ash after the August 12th 1991 eruption.
- Enrichment in SO_4, Cl, Na and Ca ions: measured levels were 330 mg/L SO_4 and 40 mg/L Cl one week after the ash fall.
- Toxic F concentrations were not detected.

Montserrat study

A recent study by *Forbes et al. 2003* concluded that volcanic ash emissions adversely affected the respiratory health of children living on the island of Montserrat, British West Indies. The Soufrirere Hills Volcano, Montserrat, erupted regularly between 1996-1998 producing fine ash that was often deposited over the small island. They carried out a questionnaire survey on school children of ashthma diagnosis, respiratory symptoms and exercise induced bronchoconstriction (EIB), and compared it to exposure to volcanic ash.

About 13-20 wt% of the ash particles from the main ash-fall deposits are less than 10 microns in mean diameter (PM_{10}) and contained 10-24 wt% cristobalite. The respirable fraction (<4 microns) comprises between 45-55 wt% of the PM_{10} fraction. Cristobalite enrichment was most pronounced in the sub-2 microns fraction (Horwell et al. 2003). About 1-8 wt% of the PM_{10} fraction was less than 2 microns diameter (Forbes et al. 2003). The deposits were easily re-suspended by wind and human activity so personal exposures were potentially high. The concentration of particles re-suspended by vehicles on Montserrat was found to decrease exponentially with height above ground: PM_4 exposure for children was typically three times the level for an adult. Samples of re-worked ash (aeolian / vehicle origin) had lower concentrations of respirable ash compared to primary ash samples.

Proposed Hudson investigation

Aims: To evaluate the long-term health effects from exposure to ash fall-out from the 1991 Cerro Hudson eruption plume on the population of the Argentine Patagonia region.

Methods: A survey (questionnaire and examination) of respiratory, pulmonary, occular and dermatological symptoms in people exposed to 1991 Hudson ash in the Provincia de Santa Cruz, Argentina. Records and support will be provided by the Argentine Ministry of Health, Provincia de Santa Cruz Ministry of Health and the National University of Cordoba. Factors such as age, height, sex, exposure to ash, and habits such as smoking will be taken into consideration. This data will be statistically analysed and compared to an identical survey of people (from a similar socioeconomic status) in the country not directly exposed to ash-fall out or re-mobilisation of ash deposits. Ultimately, a geospatial health risk map will be produced for people exposed to the 1991 Hudson ash.

Background: There was a compact population of approximately 70 000 people living in the districts most heavily inundated with ash fall-out at the time of the Aug. 12-15th 1991 eruption *(see figs. 4 & 6; table 1)*. Heavy reworking of the deposit by strong winds after the eruption extended ash exposure of the local population by several months, and may still continue to pose a hazard through re-suspension of fine material.

Argentine collaborators

Dra. Cecilia Cravero — Instituto de Altos Estudios Espaciales "Mario Gulich" (organisation created through an initiative between CONAE and the National University of Cordoba).
Dra. Corina Risso — Departamento de Geología, Area Riesgo Volcánico, FCEyN-Universidad de Buenos Aires.
Dr. Roberto Scasso — Dpto. de Cs. Geológicas, Ciudad Universitaria, Buenos Aires.
Dr. Jose Viramonte — Universidad Nacional de Salta, Argentina.

Looking for expertise

This project is still in its infancy. We encourage interest from others to collaborate on this project which has full backing from the **IVHHN** *(http://eis.bris.ac.uk/~glcjh/ivhhn/index.html)*. This investigation presents an excellent opportunity to study the long-term health effects from exposure to fine volcanic ash. Please contact Adam Durant or Dr. Bill Rose (Michigan Tech. University) for more information by email:

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Acknowledgements

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