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FROM. Norman G. Banks US Geological Survey /UN Adviser

SUBJECT: Hudson Volcano Report

DATE: 20 September 1991

Attached is a preliminary draft (with 3 tables of analyses) of the INTRODUCTION/SUMMARY section of our report of the AUG-SEPT UN mission to assist Chile and Argentina on some aspects of the eruptions of Volcán Hudson, Chile. I thought it best to send this lead section to the distribution now, because the full draft of our preliminary report is behind schedule owing to the add'l stop in Argentina and the necessity of my attendance at the EST Officer's workshop in Washington (on Monday) in preparation for my new position in the US Embassy in Chile early next year. I will continue to work on the report while in Washington, and after receiving input that is pending on the seismicity from G. Fuentealba (UFRO) and on analyses/maps/samples from Argentina (Corbella and Haller), I will complete the preliminary report, hopefully within 2-3 weeks, with the final report to follow 2-3 weeks thereafter.

Please let me know by telephone or FAX of any errors or omissions of observation and fact in the Summary, so that they can be corrected and included in the actual report.

*****5 pages of report and 4 pages of tables follow*****

PRELIMINARY REPORT OF THE UNITED NATIONS MISSION TO VOLCAN HUDSON, CHILE

21 AUGUST -- 15 SEPTEMBER 1991

NORMAN G. BANKS and MARK IVEN

U. S. GEOLOGICAL SURVEY

INTRODUCTION AND SUMMARY

This report presents, in preliminary form, the technical data produced and observations made during our UN-sponsored mission of approximately 3 weeks to assist the Chilean and Argentinean governments with certain aspects of their response to the 8-15 August 1991 eruptions of Volcán Hudson, southern Chile. Because the report is preliminary, and produced by non-residents with limited time on site, the evaluations and recommendations herein SHOULD NOT BE considered an infallible forecast of the future expected behavior of the volcano, NOR an all-encompassing guide for direction of improved response to the current unrest. There undoubtedly are some errors of fact as well as both omitted and unnecessary observations and recommendations that are endemic to a visiting consultant. Our final report, to be expected in 3-5 weeks, will be improved through review by our Chilean and Argentinean counterparts who continue to work on the problems associated with the eruptions and continuing unrest of the volcano, by incorporation of more analytical data, by more thorough consideration of our field notes, and, perhaps, by new events that might occur at Volcán Hudson.

Our mission was charged specifically with assisting Chilean and Argentinean efforts in the evaluation of (A) the potential for environmental fluorine toxicity presented by the volcanic eruptions of August 1991, and (B) the current and potential future hazards presented by the volcano during this cycle of unrest. Our findings, when coupled with collateral studies by our Chilean and Argentinean colleagues indicate (1) low likelihood of acute fluorosis for grazing animals and essentially none for humans in Chile and Argentina; (2) an uncertain, and perhaps non-existent, potential for low-level fluorosis in both plume areas of the eruptions, (3) existence of certain but incompletely evaluated hydrologic hazards facing the Rio Ibañez and perhaps also the Rio Murta vallies in Chile and several others in both Chile and Argentina, (4) probably measureable impact on grazing animals and possibly fish from reduced food sources and gastrointenstinal problems related to ash ingestion; (5) high expectation of accelerated wear of machinery, of frequent failure of electronic components, and of degraded living conditions (and perhaps some some impact on the health) for the human and animal populations in the southeastern plume area from Chile Chico-Fachinas to the Argentinean coast, perhaps for years, owing to dry climate, strong winds, and airborne reworking of the fine ash, and (6) a potential for resumed volcanic activity that could broaden the scope of the impact and which, unfortunately, is not being monitored at the level that could provide the timely short- and medium-term forecasting needed by civil defense authorities for further response to the volcano crisis. In the long-term, however, the overall effect of the eruption will be positive. The coarse deposits on the Chilean side of the border can be economically exploited, and the nutrient-rich addition to the soils in Chile and the Patagonian pampa will improve the growth of grass and shrubs used as feed by grazing animals. However, land use planning should be employed to guard against overuse of this expected benefit, and a careful long-term statistical study should be designed and immediately implemented to study the short-, medium-, and long-term positive and negative effects of the ash deposits on the plants, animals, and humans.

Delayed and reduced access to the field in Chile limited the scope of our evaluations and resulted in forecasts with less than satisfactory certainty about the hydrological hazards that face the Río Ibáñez valley, possibly the Río Murta, and perhaps other Chilean and some Argentinean valleys. However, referral of our data to Chilean and US debris flow specialists, plus the additional field work we discussed with our colleagues, may provide the information necessary for civil officials to better plan and direct preventative measures for expected flooding and possibly also post-eruptive debris flows in the affected valleys. The delayed start in Chile also restricted the time available to study the impact of the eruption in Argentina to only two partial days of conferences in Buenos Aires. Thus, evaluation of fluorine toxicity and, in particular, the short and long-term health effects of the deposits and the wind-borne ash are not as clear in Argentina as they are in Chile. However, our Argentinean colleagues outlined the extensive field studies that they have done, and they will be providing their data for consideration in the final report.

We heard, and read news stories, postulating potentially catastrophic loss (as high as 50%) of the reported 3 million sheep and 1 million beef cattle in the affected area of Patagonia because of burial of grass, filling of water holes by the blowing ash, and ash-blinding of animals. Also health hazards to both animals and humans are feared because of potentially high amounts of respirable fine ash in the area. We were unable to obtain information to clarify these hazards, to allay fears, or to provide informative statistics on the losses to date in the animal population, although one information source places these losses at only 200 sheep in Santa Cruz Province, Argentina. Thus, we outlined a program that would generate the statistical data necessary to track the impact of the August 1991 eruptions of Volcán Hudson, and the expected arrival within the next week of a USAID-funded volcano-experienced physician and veterinarian should assist clarification of the threat to human and animal health.

The eruptions were significant (1-2+ km^3 of magma) but not huge events by volcano standards. The initial 8-9 August eruption (beginning about 1820 h, 8 August) was from a basaltic (50% SiO_2) dike, northwest and partly inside the 10x7-km, ice-filled, caldera. The basalt erupted both as a fire fountain and phreatomagmatically, producing a tephra and ash column 12 km high, scoria flows that covered 10 km^2 of the western caldera floor and some unknown area outside of the caldera, a 4-km-long lava flow over the Huemules glacier, long-lived (12 hours) water floods down Río Huemules and Río Sorpresa valleys, and a rather low-volume (** km^3) airfall deposit to ** km north of the volcano. This ash had a moderate level (100-300 ppm dry weight) of soluble fluorine that was quickly reduced to 2-10 ppm by heavy rains during the next 2 weeks. Grass growing through this deposit has a background fluorine content of about 30 ppm. The 12-15 August eruption may have been due to secondary boiling triggered by intrusion of the 8 August, or other, basaltic dikes into the andesitic magma body under the caldera; bombs and lapilli of pumiceous andesite (60% SiO_2) mixed with chilled basalt are common in the airfall deposits. The 3-day andesitic eruption produced a strong plinian column that ejected pyroclastic material into a very strong SE-directed stratospheric wind (185 km/hr) that kept the plume narrow even 700 km from the volcano. Ballistic pumiceous bombs 1 meter in diameter were found 10 km from the vent where airfall deposits were more than 2.5 meters thick. The 10 cm isopach reached just SE of Chile Chico (120 km SE of the vent) and 1-2 cm of ash was deposited at the Argentinean coast. Fortunately, pyroclastic flows did not spill onto the outer snow-covered flanks of the summit during this episode, and no additional mudflows were reported. However, secondary water and pumice flows were forming on the volcano's flanks during daily melting of the snow within days of the eruption. As most of the thick deposits on the steep mountainous terrain SE of the volcano are on and interleaved with snow, downslope movement and associated hydrological problems for the downstream vallies are certain to accelerate as the summer melting and rains begin. The andesitic ash in Chile had low amounts of soluble fluorine (<20 ppm), and grass covered by or growing though the ash deposits has relatively low of background fluorine contents. Also, analysis of fine fractions of the Chilean deposits suggest that downwind (Argentinean) fluorine values will not be significantly higher.

With the database at hand, we find it most difficult to make any forecasts about the future expected behavior of the volcano. In the first place, there is no hazards map for the volcano nor is there a detailed history of its past activity. As a result, we are unable to apply the past as the key to forecasting the future. Secondly, strong M=2-3 earthquakes continued in the weeks following the eruptions, and were still continuing after our departure. Plot of this energy release does not describe the logarithmic decay typical of volcanoes which cease activity following eruptions of the size that occurred during the August 1991 events. Thirdly, monitoring began at minimal level after, not before, the eruption, and it ceased 3 September after only 2 weeks, despite continuing seismicity felt as far as Coyhaique (80 km). Thus, with neither a baseline established, nor sufficient monitoring, we can offer only the two end-member alternatives to the continuing strong seismic activity: a) the edifice is adjusting gravitationally to the ejection of the 1-2 cubic kilometers of magma, or (2) basaltic dikes continue to intrude the edifice. If the later, the potential for additional, perhaps even larger, eruptions exists.

Our findings, recommendations, and preliminary field and laboratory data were given verbally together with analytical tables and maps during nearly a dozen meetings and debriefings (also in hard copy; see 10 September 1991 memorandum) to the concerned authorities before leaving both countries (to the Intendencia and Comite Ejecutiva de Emergencia in Coyhaique; to ONEMI and SERNAGEOMIN in Santiago; to a number of departments and ministries in Argentina; and to PNUD and US embassy offices in both countries).

Among our recommendations are: 1) immediate follow through on the hydrologic hazards presented by the new volcanic deposits; 2) initiation of a well-supported and complete evaluation of the possible volcano hazards of the volcano; 3) establishment and maintenance of a vigorous and appropriate monitoring and alarm program for potentially impending eruptions and to assist confident economic recovery of the region with confident identification of cessation of this cycle of eruptive activity; 4) careful statistical study of the effect of the ash deposits on the grazing animals in the affected area; (5) a strong plea for the governments of both nations to support significant, long-term, joint and meaningful geologic hazards programs to assist better preparation and response to the next eruption that is certain to impact both countries along more than a thousand kilometers of common border. Clearly needed is a cadre of volcano hazards volcanologists in both countries with sufficient critical mass to jointly or independently anticipate and manage the eruptions that are sure to occur in the future. Encouragement of such a group will require better wages as well as governmental and societal prestige for those who wish to dedicate their careers to what for Chile and Argentina is a necessary profession.

The report will also provide a few observations and recommendations based on experience during other volcano crises where society and active volcanoes coexist. Among these are the need: (1) to establish executive coordinating committees that meet regularly to coordinate and redirect information, studies, and resources, not only within various disciplines (volcanology, civil response, health aspects, economic recovery, press, etc.) but between them; and (2) implementation of regular (e.g. every night at 6 PM) radio and newspaper bulletins that distribute the information about the volcano, hazards, and governmental response and findings to the people and business interests in the area. Past experience indicates that such communication builds confidence in government and morale of the population and thus provides earlier return of hope. Lack of communication can result in erosion of confidence, rumors, and needless damage to or stagnation of economic recovery.

Contributions to the Chilean study were made by volcanologists and seismologists of SERNAGEOMIN, the Universidad de Chile (UC), and the Universidad de la Frontera (UFRO). Drs. Hugo Moreno and José Naranjo (UC and SERNAGEOMIN), in particular, were major partners of effort and thought at many planning and response meetings and at some 60 sites in the field where volcanic deposits (60 sites), water (30-40 sites), and grass (15-20 sites) were sampled and described. Several flights over the caldera and the areas of airfall deposits, and the examination of various video segments added to the geologic reconnaissance of the eruptive events and assessment of potential hazards of Volcán Hudson. Our studies were also augmented by 2 field trips and sampling of remote sites by Carabinero teams, one up to the headwaters of Rio Ibañez and the other to the toe of the Huemules glacier. About 40 ash and 30 water samples were processed and analyzed on site for F, Cl, pH, and conductivity with the portable Ion Selective Electrode (ISE) equipment brought by the UN/USGS team. Additional samples were shipped to the US for further analyses or were submitted to SERNAGEOMIN; some of the samples were given to Dr. Alberto Villa of the Universidad de Chile (UC) for F analyses. Dr. Villa kindly allowed incorporatation of these data and other analyses he has done.

In Argentina, Dr. Hugo Corbella (CONOCIT), Dr. Miguel Haller (Univ. de la Patagonica), Lic. Hector Ostera (CONICET), and Drs. Roberto Page and José Mendia (Dirección Nacional de Mineria y Geologia) provided us with a fruitful interchange of science and hazards assessment on the deposits and special problems of airborne reworking of the ash in Santa Cruz Province, Argentina. We are expecting additional data from this source that will be incorporated in the final report along with some of the ideas spawned during these meetings.

We were supported financially and directly in the field and in both capitols by the United Nation Development Program in Santiago and Buenos Aires, and in Chile by the Oficina Nacional de Emergencia of Chile (ONEMI), esspecially ONEMI's field Manager Cristian Peña. Many other individuals and additional resources of the Intendencia (Coyhaique), EMSAA (Coyhaique), Carabineros, and Fuerza Aerea also supported our work in Chile. Most of the sampling and hazards observations we made in Chile would have been impossible without the interest, willingness, and skill of our Carabinero and Fuerza Aerea pilots and crews, with whom it was a very definite pleasure to work.

ⅽE 1--Analisis Quimico de Tipo Electrodo Ionico Selectivo
F y Cl en proporcion al peso seco de la ceniza

LOCALIDAD	FECHA	Nu. Muestra	Fracion	Commentario	Anion Soluble en La Ceniza F	Cl	pH 10/1 H2O/Ash	CONDUCT. u mol/cm
MA POR SURESTE (12-15 AUG)					1.5			
le Chico	12-Aug-91	A12	Compuesto	Seca	13	175	6.3	465
le Chico	12-Aug-91	A12	(1.0)0.5 mm	Seca	15	147	6.3	
le Chico	12-Aug-91	A12	)0.5 mm	Seca	14	175	6.9	490
le Chico	13-Aug-91	A13	Compuesto	Seca	5	90	6.3	305
le Chico	13-Aug-91	A13	(1.0)0.5 mm	Seca	5	66	6.4	205
le Chico	13-Aug-91	A13	)0.5 mm	Seca	7	102	6.3	380
le Chico	14-Aug-91	A14	Compuesto	Seca	4	72	6.1	175
le Chico	14-Aug-91	A14	(1.0)0.5 mm	Seca	4	60	6.2	160
le Chico	14-Aug-91	A14	)0.5 mm	Seca	5	102	6.3	270
le Chico	15-Aug-91	A15	Compuesto	Seca	4	72	6.1	
le Chico	15-Aug-91	A15	(1.0)0.5 mm	Sece	4	69	6.2	
le Chico	15-Aug-91	A15	)0.5 mm	Seca	5	102	6.3	
le Chico	23-Aug-91	NB91HD2	Compuesto		9	24	6.3	
le Chico	23-Aug-91	NB91HD2	(1.0)0.5 mm		7	22	6.6	
le Chico	23-Aug-91	NB91HD2	)0.5 mm		8	21	6.7	
ile Chico	23-Aug-91	NB91HD2	Capa de sal		35	2197	6.3	2800
ili Chico	29-Aug-91	*	Compuesto		1.00	18.6	7.2	380
ili Chico	29-Aug-91	*	Compuesto		0.73	9.3	6.6	430
ili Chico	29-Aug-91	*	Compuesto		0.94	24.2	6.7	300
ino→)C.Castillo	27-Aug-91	NB91HD8	Compuesto		2	7	6.8	43
ente C.Castillo	27-Aug-91	NB91HD10	Compuesto		2	(0.6	6.4	20
ente C.Castillo	27-Aug-91	NB91HD10	(1.0)0.5 mm		2	(0.6	6.5	28
ente C.Castillo	27-Aug-91	NB91HD10	)0.5 mm		5	(0.6	6.5	14
lla Cerro Castillo		JAN 6	Compuesto		6.3			
o Ibanez		JAN 4	Compuesto		8.1			
o Ibanez		MG-1	Pomice		18	244		
o.Ibanez	27-Aug-91	NB91HD14	Compuesto		4	8	7	78
o.Ibanez	27-Aug-91	NB91HD14	(1.0)0.5 mm		3	5	6.3	63
o.Ibanez	27-Aug-91	NB91HD14	)0.5 mm		5	9	7.9	79
rca Fachinas	29-Aug-91	NB91HD21	Compuesto		4	60	4.9	570
rca Fachinas	29-Aug-91	NB91HD24	Compuesto		1	8	6.2	
chrane Aeropto.	28-Aug-91	NB91HD16	Compuesto					
Rio Ibanez	31-Aug-91	NB91HD22	Compuesto		7	201	6.1	920
on	31-Aug-91	NB91HD33A	Compuesto					
o Cajon	31-Aug-91	NB91HD33B	Compuesto					
o Cajon	31-Aug-91	NB91HD33C	Compuesto	Toda la muesta esta (0.5 mm	3	7	6.7	615
o Cajon	31-Aug-91	NB91HD33D	Compuesto	Toda la muesta esta (0.5 mm	2	17	6.7	1080
o Cajon	31-Aug-91	NB91HD33E	Compuesto		5	80	5	510
Cajon	31-Aug-91	NB91HD33F	Compuesto		6	48	6.7	615
Furioso	31-Aug-91	NB91HD34	Compuesto					
o. Murta	01-Sep-91	NB91HD35	Compuesto		1	17	6.5	
MA POR NORTE (8-10 AUG)								
o.Aysen Aeropto.	28-Aug-91	NB91HD15	Compuesto	Toda la muesta esta (0.5 mm	2	(0.2	6.4	11
o. Aysen	08-Aug-91	JAN 0A	Compuesto	Seca	315	597		
o. Aysen	08-Aug-91	JAN 0B	Compuesto	Seca	225			
o. Cisnes	08-Aug-91	MG-1	Compuesto	Seca	304	530		
to. Cisnes	30-Aug-91	NB91HD29	Compuesto	Seca, toda la muesta esta (0.5 mm	84	102	6.1	165
40 km E. Pto. Cisnes	30-Aug-91	NB91HD28	Compuesto	Toda la muesta esta (0.5 mm	4		6.5	10
2 Km S of Puyuguapi	30-Aug-91	NB91HD27	Compuesto	Toda la muesta esta (0.5 mm	3	(0.5	6.2	13

guapi Aerporto.	30-Aug-91	NB91HD26	Compuesto	3	45	5.2	65
unta	30-Aug-91	NB91HD25	Compuesto	1	51	7.1	

Analisis colorimetrico de EMSSA

: 2--Analisis Quimico de Tipo Electrodo Ionico Selectivo
F y Cl en Muestras del Agua

:lidad		Nu. Muestra	Tipo	Commentario	F	Cl	pH	CONDUCT. u mol/cm
ite Maximo por salud					1.5	250		
ca C. Castillo	27-Aug-91	NB91HD11	Arroyo		0.22	1.2	7.5	100
:in--)Pto.Ibanez	27-Aug-91	NB91HD12	Posa		0.38	3	7.9	267
in--)Pto.Ibanez	27-Aug-91	NB91HD14	Posa		1.10	1.3	7.4	450
). Ibanez	27-Aug-91	NB91HD14	Lago		0.25	0.8	7.5	79
[illegible]	27-Aug-91	NB91HD14	Agua Potable		0.27	1.2	7.1	267
	27-Aug-91	2lake???	Lago		[illegible]	[illegible]	[illegible]	[illegible]
:hrane	28-Aug-91	NB91HD16	Agua Potable	Antes Cl,en campo	0.16	1.5	7	52
:ca Chile Chico	29-Aug-91	NB91HD17	Arroyo	Turbid	0.50	16	7.9	640
:ca Fachinas	29-Aug-91	NB91HD22	Lago	Clear	1.10	16	6.6	470
) Aviles	29-Aug-91	NB91HD23	Rio		(0,2	1.8	6.9	80
Junta Aeropuerto	30-Aug-91	NB91HD25	Posa		0.30	(0,6	6.1	11
/uguapi Aerporto.	30-Aug-91	NB91HD26	Posa	Near Sea	0.52	0.8	6.0	14
Km S of Puyuguapi	30-Aug-91	NB91HD27	Aroyo glacial		(0,2	1.8	6.6	26
:0 ' E. Pto. Cisnes	30-Aug-91	NB91HD28	Nieve con ceneza					
Pto. Cisnes	30-Aug-91	NB91HD30	Posa		0.30	2.5	6.4	15
.o Furioso	01-Sep-91	NB91HD34	Rio		0.25	0.6	6.5	02
:o. Murta	01-Sep-91	NB91HD35w1	Posa		(0,2	(0,5	6.6	20
:o. Murta	01-Sep-91	NB91HD35wp	Agua potable		3.00	0.8		105
:o Chiflon	02-Sep-91	NB91HD41	Rio		0.50	10	6.9	325
erca Rio Avellano	02-Sep-91	NB91HD48	Nieve con ceniza		1.40	18	6.8	575
io Ibanez	27-Aug-91	R-IBAN-1	Rio		1.10	4.2	7.1	413
io Ibanez	29-Aug-91	R-IBAN-2	Rio		1.30	25	6.6	860
io Ibanez	29-Aug-91	R-IBAN-3	Rio		0.35	4.2	6.7	155
:haique	26-Aug-91	Intendecia	Agua Potable		(0,2	2.4	7.3	
hile Chico	23-Aug-91	Hospital	Agua Potable		(0,2	(0,5	7.2	
hili Chico	23-Aug-91	*	Agua Potable		0.48		6.9	98
:to. Ibanez		*	Agua Potable		0.52		7.2	200
:erro Castillo		*	Agua Potable		0.45		6.8	90
:erro Castillo	24-Aug-91	*	Agua Potable		0.02	6.1	7.4	--
Pto. Chatabuco		*	Agua Potable		0.80		7.3	30
Pto. Chatabuco	13-Aug-91	*	Agua Potable		0.10	2.8	7.5	--
Pto.Aysen		*	Agua Potable		0.56		6.7	90
Pt[illegible]en	13-Aug-91	*	Agua Potable		1.50	22.3	6.7	300
[illegible]		*	Agua Potable		0.55		7.2	90
Lago Caro		*	Lago					
Chili Chico	23-Aug-91	*	Agua Potable		0.06	2.8	7.3	--
Chili Chico	28-Aug-91	*	Agua Potable		0.50	3.7	7.5	63
Chili Chico	28-Aug-91	*	Agua Potable		0.37	8.8	7.2	310
Chili Chico	28-Aug-91	*	Agua Potable		[illegible]	[illegible]	7.4	175
Chili Chico	28-Aug-91	*	Agua Potable		0.23	7.9	7.5	150
Cochrane	22-Aug-91	*	Agua Potable		0.10	2.8	7.5	--

* = Analisis colorimetrico de EMSSA

5--Analisis Quimico de Pasto por fluor. Por H. Villa, Univ. Chile

idad	FECHA	Nu. Muestra	Tipo	Commentario	F
POR SURESTE (12-15 AUG)					
a Cofre		#3			72.5
Castillo		JAN-4	Pasto de miel		64.0
Chico	28-Aug-91	NB91HD2	Pasto de miel		151.2
Chico		#19			95.5
Chico		#13			85.8
Chico		#14		testigo sin ciniza	102.0
ane	28-Aug-91	NB91HD16	Pasto de miel		29.0
co-Fachinas Via	29-Aug-91	NB91HD21	Pasto de miel		69.5
anco		#2			10.5
nas		#16			4.3
nas		#17			39.9
o Ibanez		#10		testigo sin ciniza	114.0
Ibanez		#7		testigo sin ciniza	101.0
Murta		#9			35.3
POR NORTE (8-10 AUG)					
iqr		JAN-1	Pasto de miel		15.7
ropuerto	30-Aug-91	NB91HD25	Pasto de miel		44.1
ysen	28-Aug-91	NB91HD15A	Pasto de miel		48.9
sen	28-Aug-91	NB91HD15B	Pasto de miel		29.0
ysen		JAN-0	Pasto de miel		215.0
ysen		AV-1	Pasto de miel		280.0
lanes	30 Aug 91	NB91HD22	Pasto de miel		27.6
api Aerporto.	30-Aug-91	NB91HD26	Pasto de miel		19.2