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Evidence of 14 New Subglacial Lakes in the Dome C-Vostok Area

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INTRODUCTION

In the last few years subglacial lakes have been of great interest to the scientific community for various reasons. The lakes could be an unknown extreme habitats, which have been isolated from the terrestrial biosphere for a long time. They may have formed before the ice sheet and could perhaps reveal environmental conditions prior to its formation. Lastly, they may play a role in the current dynamics of the ice sheet.

Strong radar reflections from the base of the ice sheet can generally be ascribed to either water-saturated basal sediments or subglacial lakes (Oswald & Robin, 1973). Based on radar data alone, the identification of lakes is possible if other features are present: flat and quite horizontal reflectors with nearly constant echo intensity and sharp edges similar to the margins of a catchment basin (Siegert et al., 1996; Siegert & Ridley, 1998; Gorman & Siegert, 1999; Siegert, 2000; Tabacco et al., 2002). Subglacial lakes can be expressed in the overlying ice sheet as extremely flat surfaces with respect to the surrounding slopes (Ridley et al.,1993; Kapitsa et al.,1996 ; Siegert & Ridley,1998; Tabacco et al., 2002).

To date, about 70 lakes have been discovered in all of Antarctica (Siegert et al.,1996); 21 of these are located in the Dome C-Vostok region.

LAKE IDENTIFICATION

We report evidence of new lakes in the Dome C-Vostok region (Fig. 1) from eleven radar missions (airborne and ground-based surveys) completed during the Italian expeditions in 1995, '97, '99 and 2001. The data were acquired by means of a radar system operating at 60 MHz frequency. Thirty-one radar tracks were interpreted as lake reflections. By comparing the location, ice thickness and surface anomalies in all these radar tracks, some were ascribed to the same lake; consequently, the number of lakes dropped to 18 (Tab. 1 & Fig. 1).

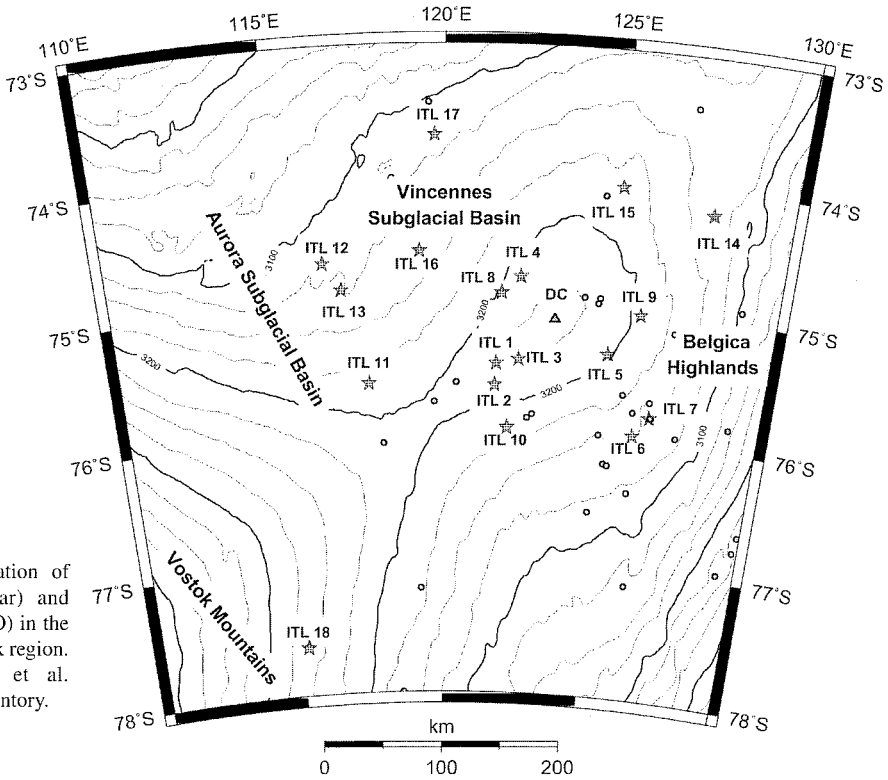

Fig. 1 – Location of new lakes (star) and Siegert lakes (O) in the Dome C-Vostok region. From Siegert et al. 1996 lakes inventory.

Ten lakes are located in restricted areas of the Belgica Highlands with surface slopes of less than 0.8 m/km. Their length (apart from lake ITL 7, located over a sharp local depression, and ITL 10, located at the boundary between the Aurora Basin and Belgica Highlands) ranges from 1.1 to 5 km. Ice thickness ranges from 3000 to 3500 meters (except in ITL 4, located over a sharp local depression), the elevation of the lake surface varies from -373 m to +192 m (WGS84; except in ITL 4). All the lakes have sharp shorelines with high slope gradients (up to 300 m/km). Based on the catchment basin morphology, we estimated that the maximum water depth (measured in ITL 4) is about 100 m. The radar tracks of the lake are not associated with local surface features; this confirms that the lakes are too small to modify surface features. Figure 2 shows the radar section of ITL 5 (see Tab. 1): a typical lake in the Belgica area.

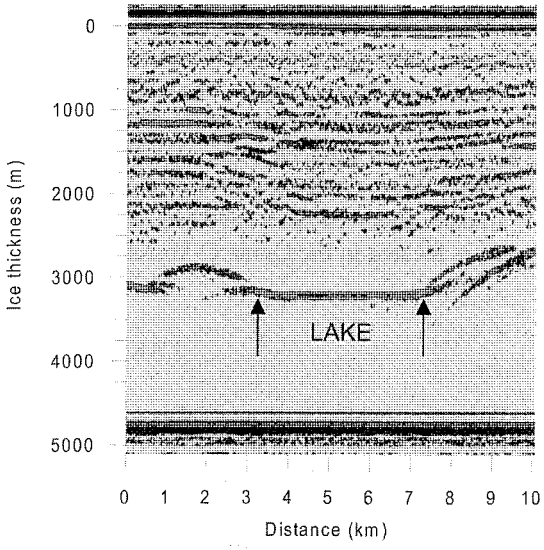

Fig. 2 – Radar section of ITL 5.

Tab. 1 – Features of subglacial lakes derived from radar tracks.

Lake Id	*Radar Track Id*	*Track Length (m)*	*Longitude °E*	*Latitude °S*	*Ice Thickness (m)*	*Elevation (m) (WGS84)*
ITL 1	it 1	2178	121.630	75.460	3570	-354
	it 2	1163	121.379	75.509	3587	-373
ITL 2	it3	1142	121.607	75.624	3513	-304
ITL 3	it4	1712	122.315	75.422	3030	192
ITL 4	it14	3086	122.284	74.785	3769	-560
ITL 5	it15	4486	125.022	75.345	3150	53
ITL 6	it17	4453	126.028	75.954	2975	178
ITL 7 (Siegert 11)	it18	10725	126.526	75.811	3408	-259
ITL 8	it19	1993	121.732	74.913	3416	-212
ITL 9	it 23	3296	125.918	75.024	3461	-264
	it 24	3188	125.748	75.030	3463	-264
ITL 10 (Siegert 13,14)	it6	11465	122.039	75.953	3489	-305
ITL 11	it7	3369	117.686	75.608	4457	-1277
ITL 12	it21	27229	116.421	74.673	4155	-1037
ITL 13	it22	11828	116.936	74.881	4460	-1332
ITL 14 Vincennes Lake	it10	6245	127.712	74.359	4082	-946
	it13	26608	127.767	74.005	4126	-990
	it29	13814	127.730	73.957	4029	-896
	it30	12738	127.677	74.201	4040	-907
	it31	11442	127.798	74.336	4049	-914
ITL 15 Concordia Lake (Siegert 6)	it9	49758	124.900	74.059	4053	-872
	it11	15079	124.913	74.169	4082	-898
	it25	16069	125.045	74.052	4041	-861
	it26	24215	124.894	74.147	4084	-901
	it27	7600	125.179	74.026	4022	-843
	it28	10307	125.459	73.943	3953	-776
	it32	1648	125.600	73.900	3824	-648
ITL 16 Aurora Lake (Siegert 34)	it 16	14675	119.497	74.412	4055	-920
	it 20	18275	119.266	74.598	4019	-882
ITL 17	it12	9573	119.715	73.702	4034	-915
ITL 18	it5	5914	115.191	77.626	3500	-243

Four lakes are located in the Vincennes Subglacial Basin. The minimum length ranges from 10 to 50 km, with an ice thickness of 4000 to 4200 m and lake surfaces at -1000 to -800 m (WGS84), deeper than the surface of Lake Vostok. All the radar tracks are associated with local, well-defined surface features characterized by slope gradients less than 0.4 m/km; it was thus possible to evaluate, on the basis of surface slope, the real extension (up to 900 km^2), of the three larger lakes: Lake Concordia (ITL15), Lake Vincennes (ITL14) and Lake Aurora (ITL16). Figure 3 shows the Lake Concordia surface slope: the radar tracks correspond to the flat area with a gradient of less than 0.3 m/km. Based on the surface slope, we calculated that the lake covers an area of 880 km^2. Lastly, on the basis of shoreline topographies, we calculated maximum water depths: Lake Concordia, Lake Vincennes and Lake Aurora are respectively 200 m, 120 m and 100 m deep.

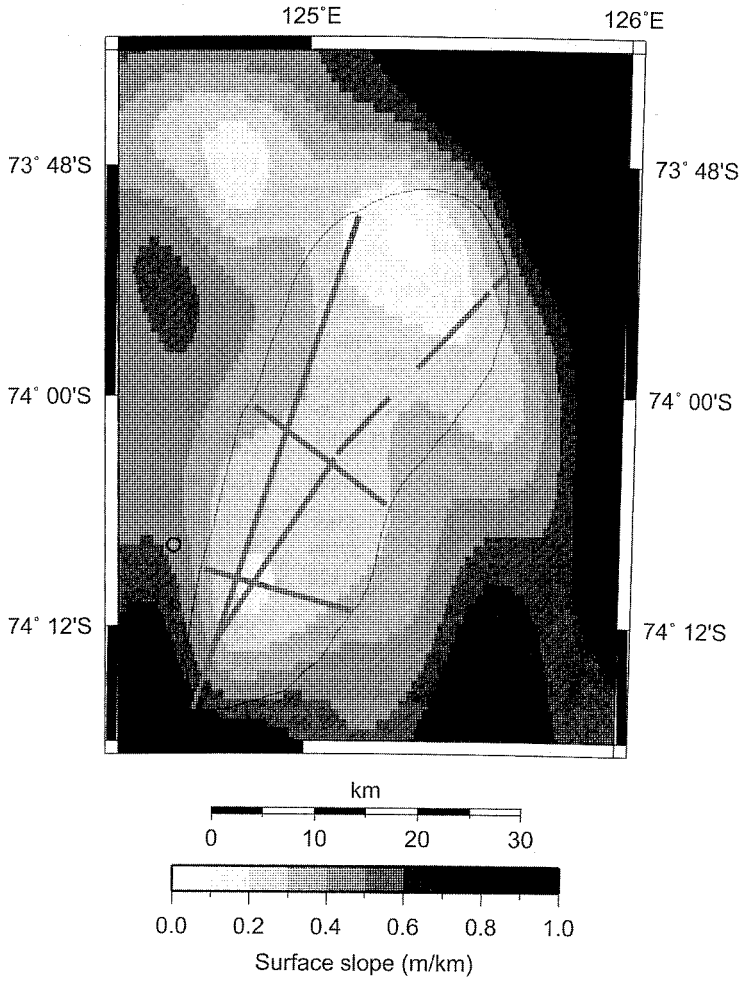

Fig. 3 – Boundaries of Lake Concordia and radar tracks of the lake.

Three lakes are located in the Aurora Subglacial Basin. Lake ITL 11 is very small (3.3 km); the lake surface is located -1270 m (WGS84) and an ice thickness of 4440 m. Lakes ITL 12 and ITL13 are located on a terraced structure of the bedrock; they are respectively 11.8 and 27.2 km long, with an ice thickness of 4457m and 4155 m, lake surfaces at about -1330 m and -1030 m (WGS84), and water depths of about 200 m. Both lakes are well-defined by a surface anomaly with a slope of less than 0.5 m/km.

One lake (ITL 18) was detected on the eastern side of the Vostok Mountains. It is about 6 km long, with an ice thickness of 3500 m at -243 m (WGS84). The radar tracks coincide with a localized surface feature with a slope gradient of less than 0.4 m/km.

Considering that four of the lakes correspond to the ones in the Siegert inventory (Siegert et al., 1996), a total of 14 new lakes were discovered which must be added to the inventory of subglacial Antarctic lakes.

CONCLUSIONS

Thirty-five lakes (14 new ones and 21 from the previous inventory) were detected in the area. Of these, 17 lakes are located in the Belgica Highlands, 7 in the Aurora Subglacial Basin and 7 in the Vincennes Subglacial Basin.

It should be noted that, although all the lakes are located near the main ice divides, their length and ice thickness range widely; therefore, statistical analyses of the distribution of lakes versus length, ice thickness or distance from the ice divide are not significant. On the contrary, if we take into account the location of lakes with respect to bedrock features, we observe that the lakes located in the Belgica Highlands have similar geometric features, which are quite distinct from those of lakes in the Vincennes and Aurora basins. The size and distribution of lakes may be correlated not only with the distance from the ice divide or ice thickness, but also with the geological setting and bed morphology; we can therefore distinguish between "Alpine lakes" (Belgica) and "Basin lakes" (Vincennes and Aurora).

The unusual concentration of lakes on the southern side of the Belgica Highlands and the absence of lakes on the western side of the Vostok Mountains need explanation. Considering that the two areas have about the same ice thickness, and that large differences in ice-flux velocities (and consequently differences in heat produced by friction) can be excluded, we suggest that it could be a positive geothermal anomaly over the Belgica Mountains.

Finally, we suggest that Lake Concordia, located about 100 km NE of Concordia Station, is an excellent candidate for future subglacial lake exploration due to its extension and water depth.

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