RECONNAISSANCE BATHYMETRY OF BASINS OCCUPIED BY PLEISTOCENE LAKE LAHONTAN, NEVADA AND CALIFORNIA

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4262

RECONNAISSANCE BATHYMETRY OF BASINS OCCUPIED BY PLEISTOCENE LAKE LAHONTAN, NEVADA AND CALIFORNIA

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Multiply SI units	*By*	*To obtain inch-pound units*
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
square kilometer (km^2)	0.3861	square mile
cubic kilometers (km^3)	0.2399	cubic mile

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ABSTRACT

The last high lake level (highstand) of Pleistocene Lake Lahontan occurred 14,000 to 12,500 years before present. During that time, Lake Lahontan occupied seven topographic subbasins. In this report, the area and volume of each of these subbasins are given as a function of lake-surface altitude. The present-day altitudes of the seven primary sills that serve to separate the subbasins also are tabulated. These data serve as a basis for continuing studies of the chemical evolution and paleohydrology of closed-basin lakes located in the Great Basin of the western United States.

Currently six rivers discharge to the Lahontan basin. The Walker River discharges to Walker Lake, Nevada; the Truckee River discharges to Pyramid Lake, Nevada; the Carson River discharges to the Carson Sink, Nevada; the Humboldt River discharges to the Humboldt Sink, Nevada; the Susan River discharges to Honey Lake, California; and the Quinn River discharges to the Black Rock Desert, Nevada, forming a shallow ephemeral playa.

Geomorphic evidence suggests that, at one or more times in the past, the Walker River discharged to the Carson Desert, and the Humboldt River discharged to the Black Rock Desert. Those stream-capture events would have led to creation of lakes in certain subbasins and desiccation of lakes in other subbasins. It follows that change of lake level does not necessarily imply change of climate.

During times of major change in the hydrologic balance, lake-level change in each subbasin is a complicated function of river discharge to that basin, and flow in or out of the basin occurring via sill pathways. Only when lake level exceeds 1,308 meters, does Lake Lahontan become a single body of water, that acts in a unified manner to changes in the regional hydrologic balance.

INTRODUCTION

During the late Pleistocene, 14,000 to 12,500 years B.P. (years before present), Lake Lahontan achieved an altitude of approximately 1,330 m, as evidenced by the estimated level of Pyramid Lake (fig. 1). Lake Lahontan at this time covered an area of 22,300 km^2 and occupied a volume of 2,020 km^3. The Lake Lahontan basin consisted of seven topographic subbasins separated by seven sills. Six rivers--the Quinn, the Humboldt, the Walker, the Carson, the Truckee, and the Susan--flowed into the system (fig. 2).

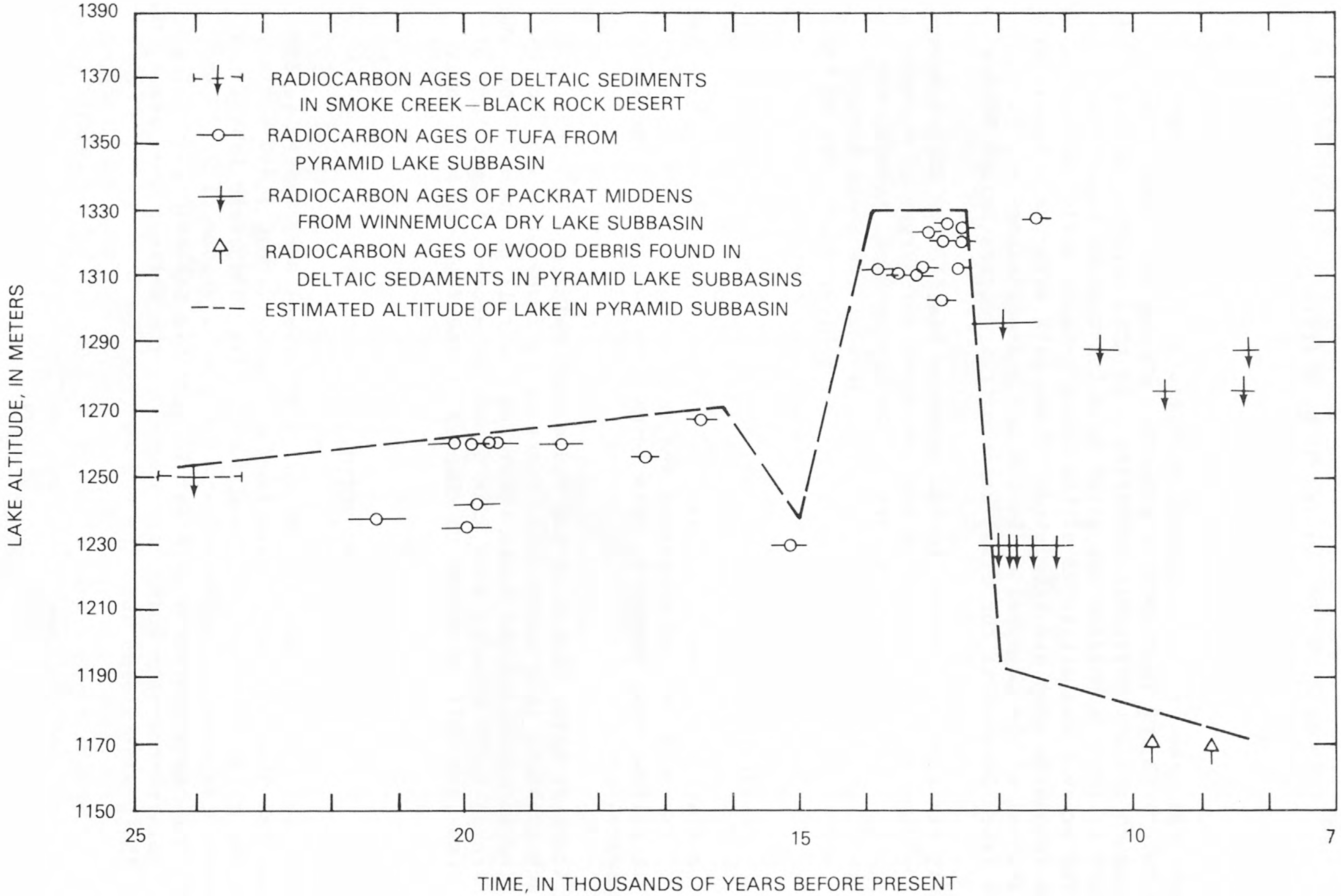

Figure 1.--Lake-level altitude in Pyramid Lake, Winnemucca Dry Lake, and Black Rock Desert as a function of time.

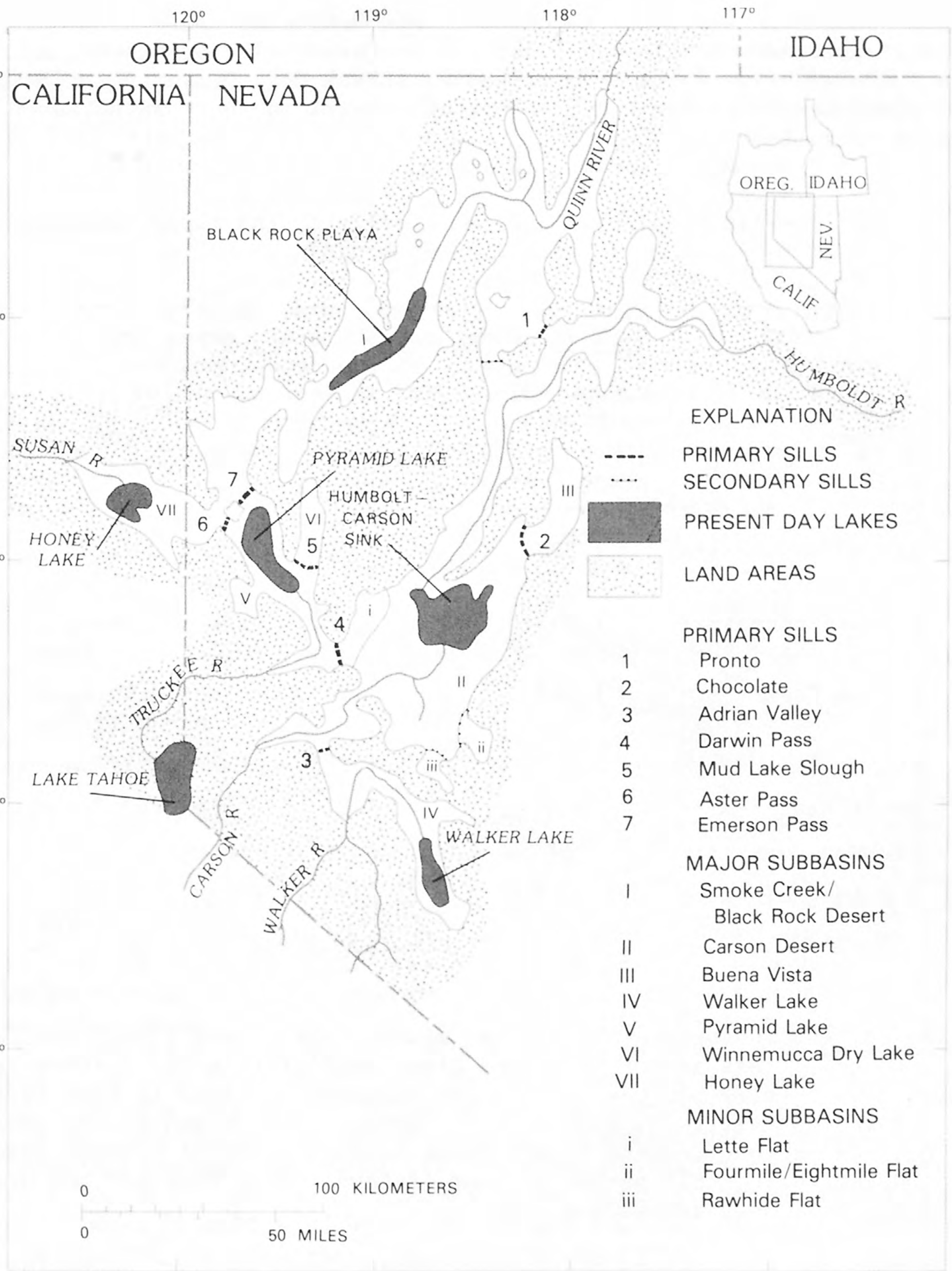

Figure 2.--Surface area of Lake Lahontan 14,000 to 12,500 years before present (modified after Mifflin, 1968).

Beginning about 12,500 years B.P., Lake Lahontan began to decline (fig. 1: Black Rock Desert data from Davis [1983]; Truckee River Delta data from Born [1972]; tufa data from Benson [1981]; packrat-midden data from Thompson and others [1985]). As water levels declined, their altitudes fell below sill altitudes (table 1); locations of these sills are shown in figure 2. Today, five surface-water bodies (Black Rock Playa, Humboldt-Carson Sink, Walker Lake, Pyramid Lake, Honey Lake) exist in four of the seven subbasins (fig. 2).

Table 1.--*Altitudes of the primary sills in the major subbasins in the Lahontan basins*

Sill name	Sill altitude, in meters above sea level		Overflow type
	Present-day (1985) (from topographic map)	Corrected for isostatic rebound and tilting	
Adrian Valley----	1,308	1,302	River diversion/ lake overflow
Pronto-----------	1,292	1,283	River diversion/ lake overflow
Darwin Pass------	1,265	1,253	River diversion/ lake overflow
Chocolate--------	1,262	1,253	Lake overflow
Astor Pass-------	1,222	1,213	Lake overflow
Emerson Pass-----	1,207	1,195	Lake overflow
Mud Lake Slough--	1,177	1,177	River diversion/ lake overflow

The collective surface area of the modern lakes today (1985) totals less than 1,600 km^2. This area is fourteen times smaller than the surface area existing 14,000 to 12,500 years B.P. The remarkable change in lake surface area, volume, and altitude, that occurred between 12,500 and 11,500 years B.P., has led various workers to speculate on the nature of climate change that occurred during this period of time (Antevs, 1952; Broecker and Orr, 1958; Morrison, 1964; and Benson, 1981).

To perform calculations of climate change, based in part on surface area and volume change as a function time, the relation of surface area and volume to altitude of age-dated, shoreline-related materials must be quantified.

The purpose and scope of this study is to provide bathymetric parameters (volume and area) for each of the Lahontan subbasins as a function of lake level (altitude above sea level). This information can be used to calculate the change in lake area and volume for individual subbasins, in which datable evidence for shorelines exists. In this way, estimates of climate change can be made for times when Lake Lahontan consisted of two or more bodies of water. To illustrate the usefulness of the bathymetric data, one hypothetical example is described for the changing topology of the Lake Lahontan system as a function of decline in lake level(s) from the 1,330-m highstand.

BATHYMETRIC METHOD

Surface areas of each basin were calculated at 5-m intervals by cutting out the area from a topographic map and weighing the cutout with an electronic balance. The area-to-weight ratio was determinded by weighing a cutout of known area. The volume of layers, each 5 m thick, was calculated by assuming the mean area of a layer was one-half the sum of the bottom and top areas. Bathymetric data calculated in this manner agree within two percent of published planimetric data for lower altitude-based data sets for both Pyramid and Walker Lake basins (Harris, 1970; Rush, 1970). Present-day sill altitudes were taken from recent topographic maps of the area; estimates of sill altitudes (table 1) probably are accurate within 2 m.

TECTONIC READJUSTMENT OF THE LAHONTAN BASIN

Since the last highstand 12,500 years ago, the Lahontan basin has undergone isostatic rebound as a result of crustal unloading. Measurements of the highest shoreline altitude throughout the Lahontan basin (Mifflin and Wheat, 1971) indicate that isostatic rebound and tilting occurred since the highest shorelines were formed. Based on these measurements, sill altitudes corrected for isostatic rebound and tilt were determined and are listed in table 1. The distribution of regional tilting with time since the last high stand of Lake Lahontan is not known, but the evidence is clear that tilting has been occurring since early Lahontan time, and, therefore, may be more evenly distributed over time. The amount of rebound correction has been calculated by subtracting the reentrant-maximum shoreline altitude (the most distant shoreline from the water load) from the measured-maximum shoreline altitude near the sill in question. This calculation yields a near-maximum value for a rise in sill altitude, resulting from isotatic rebound since the time of highest lake level. The regional-tilt correction applied to the Pronto sill has been estimated by considering the difference between northeastern reentrant-maximum shoreline altitudes and altitudes along the western reentrants, a value of about 9 m. All the other sills probably are south of the principal area of northward or northeastward tilting. The isostatic-rebound corrections are believed to be accurate to within 2 m.

BATHYMETRY OF LAKE LAHONTAN

The area and volume of each of the seven basins that comprised Lake Lahontan are listed as a function of altitude in tables 2 and 3. Note that the data are tabulated for altitudes in excess of sill altitudes. The bathymetric data are displayed graphically in figures 3 and 4. Note also that bathymetric data and sill altitude are not listed for the minor subbasins (fig. 2). The relation of surface area and volume to lake-level altitude in these shallow subbasins is not of climatic importance; however, these subbasins do represent areas of probable salt accumulations, and are, therefore, interesting from an economic standpoint. If we consider the fact that Winnemucca Dry Lake and Pyramid Lakes were joined when lake level exceeded 1,177 m, Walker Lake is unique in its sensitivity to changes in inflow (fig. 5). The lake level of Walker Lake is independent of lake levels in the other subbasins, until the altitude of its level exceeds the 1,308-m sill level at Adrian Valley. The Carson Desert and Smoke Creek-Black Rock Desert exhibit the opposite behavior; lake levels in both basins change very gradually as a function of volume changes (fig. 5).

THE EFFECT OF SILL ALTITUDE ON THE TOPOLOGY OF LAKE LAHONTAN

In this section, the influence of sill altitude on the topology of Lake Lahontan is examined. As discussed previously, Lake Lahontan existed as a single body of water, only when lake level exceeded 1,308 m. The effect of sill altitude on lake-surface topology can be isolated from other sources of topological variance (such as changes in precipitation and discharge) by adopting a hypothetical example, in which the imposition of an extremely arid climate caused Lake Lahontan to desiccate. In the hypothetical desiccation example, the 1,330-m high stand was considered the initial condition, and a uniform evaporation rate of 1.0 m yr^{-1} was arbitrarily imposed upon each subbasin.

A sequence of eight lake-surface topologies, each corresponding to decline of lake level below a particular sill altitude occurs as a result of the hypothetical-desiccation process (fig. 6). Each topology has been associated with the period of time required for lake level to decline to a given sill altitude. For example, 22 years are required for lake level to decline to the 1,208-m altitude of Adrian Valley (fig. 6b). At times, Lake Lahontan consists of as many as four separate water bodies (fig. 6f). This hypothetical-desiccation example serves to illustrate the point that the volume, surface area, and altitude of each lake in a Lahontan subbasin is a complicated function of basin topology, evaporation rate, and fluid inflow resulting from river discharge, precipitation on the lake surface, and spill to or from adjoining basins.

Table 2.--*Area of basins comprising Lake Lahontan as a function of altitude*

[Altitude of basin floor shown in parentheses]

Basin altitude (meters above sea level)	Area, in square kilometers						
	Pyramid Lake Basin	Winnemucca Dry Lake Basin	Smoke Creek-Black Rock Desert Basin	Walker Lake Basin	Carson Desert Basin	Honey Lake Basin	Buena Vista Basin
1,335	1,126	569	9,152	1,100	8,325	1,692	812
1,330	1,102	558	9,043	1,055	7,980	1,683	795
1,325	1,078	546	8,932	992	7,680	1,672	775
1,320	1,056	535	8,781	932	7,395	1,657	755
1,315	1,034	524	8,644	872	7,152	1,640	738
1,310	1,012	522	8,480	801	6,930	1,616	718
1,305	990	511	8,297	750	6,720	1,590	698
1,300	968	500	8,090	700	6,540	1,560	675
1,295	948	490	7,877	655	6,360	1,525	658
1,290	928	479	7,620	614	6,210	1,485	636
1,285	908	470	7,339	578	6,075	1,435	611
1,280	889	464	7,022	546	5,955	1,382	582
1,275	870	454	6,684	490	5,862	1,320	562
1,270	852	445	6,290	445	5,724	1,240	535
1,265	836	436	5,809	400	5,580	1,140	505
1,260	820	428	5,343	365	5,430	1,020	475
1,255	803	420	4,758	332	5,280	830	438
1,250	788	412	4,180	305	5,130	750	385
1,245	774	403	3,820	282	4,980	685	320
1,240	762	395	3,684	260	4,812	640	248
1,235	751	386	3,508	242	4,650	605	150
1,230	740	379	3,340	225	4,485	564	30
1,225	728	370	3,139	206	4,320	543	(1,229.5)0
1,220	716	362	2,950	188	4,104	529	
1,215	704	354	2,778	170	3,876	(1,216)0	
1,210	689	344	2,610	152	3,615		
1,205	674	332	2,450	141	3,300		
1,200	658	320	2,282	132	2,970		
1,195	640	307	2,120	120	2,550		
1,190	622	294	1,960	106	2,100		
1,185	604	280	640	88	1,590		
1,180	584	266	540	66	1,020		
1,175	558	250	385	10	390		
1,170	522	232	(1,170)0	(1,171.5)0	(1,173.5)0		
1,165	482	208					
1,160	456	178					
1,155	436	132					
1,150	420	52					
1,145	406	(1,149)0					
1,140	393						
1,135	380						
1,130	366						
1,125	351						
1,120	334						
1,115	312						
1,110	284						
1,105	258						
1,100	238						
1,095	217						
1,090	200						
1,085	182						
1,080	163						
1,075	140						
1,070	116						
1,065	85						
1,060	50						
1,055	8						
	(1,054.3)0						

Table 3.--*Volume of basins comprising Lake Lahontan as a function of altitude*

[Altitude of basin floor shown in parentheses]

Basin altitude (meters above sea level)	Area, in cubic kilometers						
	Pyramid Lake Basin	Winnemucca Dry Lake Basin	Smoke Creek-Black Rock Desert Basin	Walker Lake Basin	Carson Desert Basin	Honey Lake Basin	Buena Vista Basin
1,335	168.4	71.3	820.5	49.3	819.0	143.0	58.5
1,330	163.0	68.9	780.5	44.8	769.5	136.0	55.5
1,325	157.6	65.9	728.7	41.5	721.5	125.4	50.3
1,320	152.2	63.0	679.2	39.1	684.2	114.9	46.1
1,315	147.0	59.7	638.0	37.1	633.0	105.6	42.0
1,310	142.0	57.1	600.8	35.3	600.0	98.0	38.5
1,305	136.5	54.6	550.9	33.4	567.0	90.0	35.0
1,300	131.5	52.6	510.5	31.8	544.8	82.8	31.8
1,295	126.3	50.0	474.5	30.1	511.5	74.7	28.2
1,290	121.6	47.5	435.5	28.5	480.0	67.3	25.0
1,285	116.7	44.9	397.5	27.1	448.5	60.0	21.7
1,280	112.2	43.0	359.4	25.8	419.9	53.4	19.2
1,275	107.5	40.5	323.0	24.1	387.0	46.5	16.0
1,270	102.8	38.4	290.0	22.3	360.0	40.3	13.5
1,265	98.3	36.1	258.2	20.4	330.0	34.9	10.9
1,260	94.0	34.1	235.8	18.5	306.0	29.3	8.6
1,255	89.6	31.7	206.3	16.6	277.5	25.0	6.5
1,250	85.5	29.7	185.7	14.4	250.8	20.6	4.5
1,245	81.7	27.6	164.0	11.8	225.0	16.5	2.7
1,240	77.9	25.8	149.9	10.0	203.6	12.7	1.4
1,235	74.0	23.6	130.0	8.0	177.0	9.8	.4
1,230	70.6	21.9	114.0	7.0	156.0	6.5	.01
1,225	67.0	20.0	98.4	6.1	135.0	3.8	(1,229.5).00
1,220	63.9	18.3	83.5	5.5	114.5	1.0	
1,215	60.0	16.2	69.5	4.4	94.5	(1,216).0	
1,210	56.8	14.7	56.9	3.5	76.5		
1,205	53.0	12.9	44.3	2.9	58.5		
1,200	50.0	11.4	31.2	2.3	43.7		
1,195	46.8	9.6	21.4	1.6	31.5		
1,190	43.5	8.3	10.4	1.0	22.5		
1,185	40.3	6.8	5.5	.6	14.7		
1,180	37.6	5.6	2.7	.2	3.8		
1,175	34.9	4.1	.96	.03	.3		
1,170	32.3	2.7	(1,170).00	(1,171.5).00	(1,173.5).0		
1,165	29.6	1.5					
1,160	27.3	1.2					
1,155	25.0	.08					
1,150	23.0	.03					
1,145	21.0	(1,149).00					
1,140	19.2						
1,135	17.2						
1,130	15.4						
1,125	13.5						
1,120	12.0						
1,115	10.4						
1,110	9.0						
1,105	7.5						
1,100	6.1						
1,095	5.0						
1,090	4.0						
1,085	3.0						
1,080	2.3						
1,075	1.6						
1,070	1.0						
1,065	.9						
1,060	.3						
1,055	.2						
	(1,054.3).0						

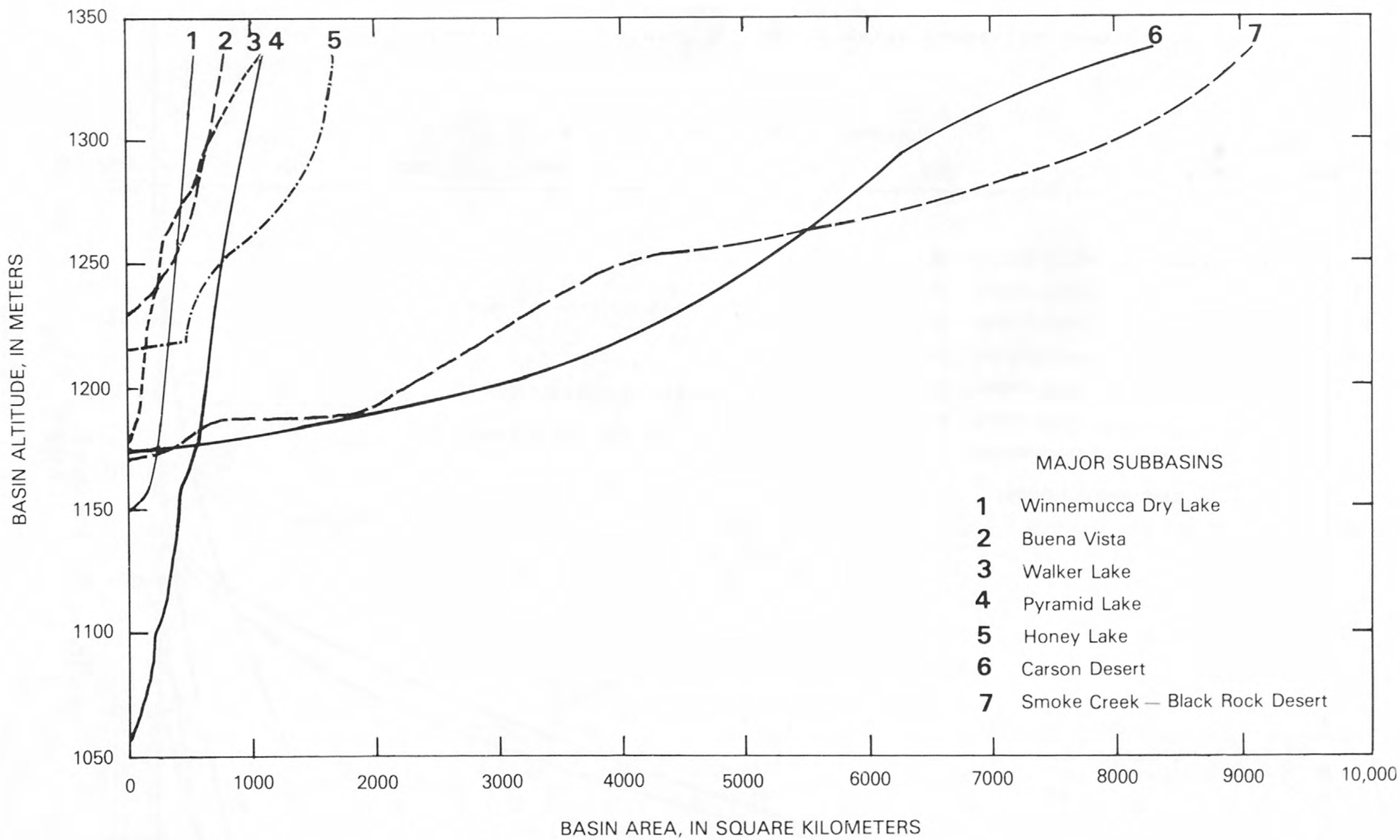

Figure 3.--Altitude surface-area plots of the seven major subbasins comprising the Lake Lahontan system.

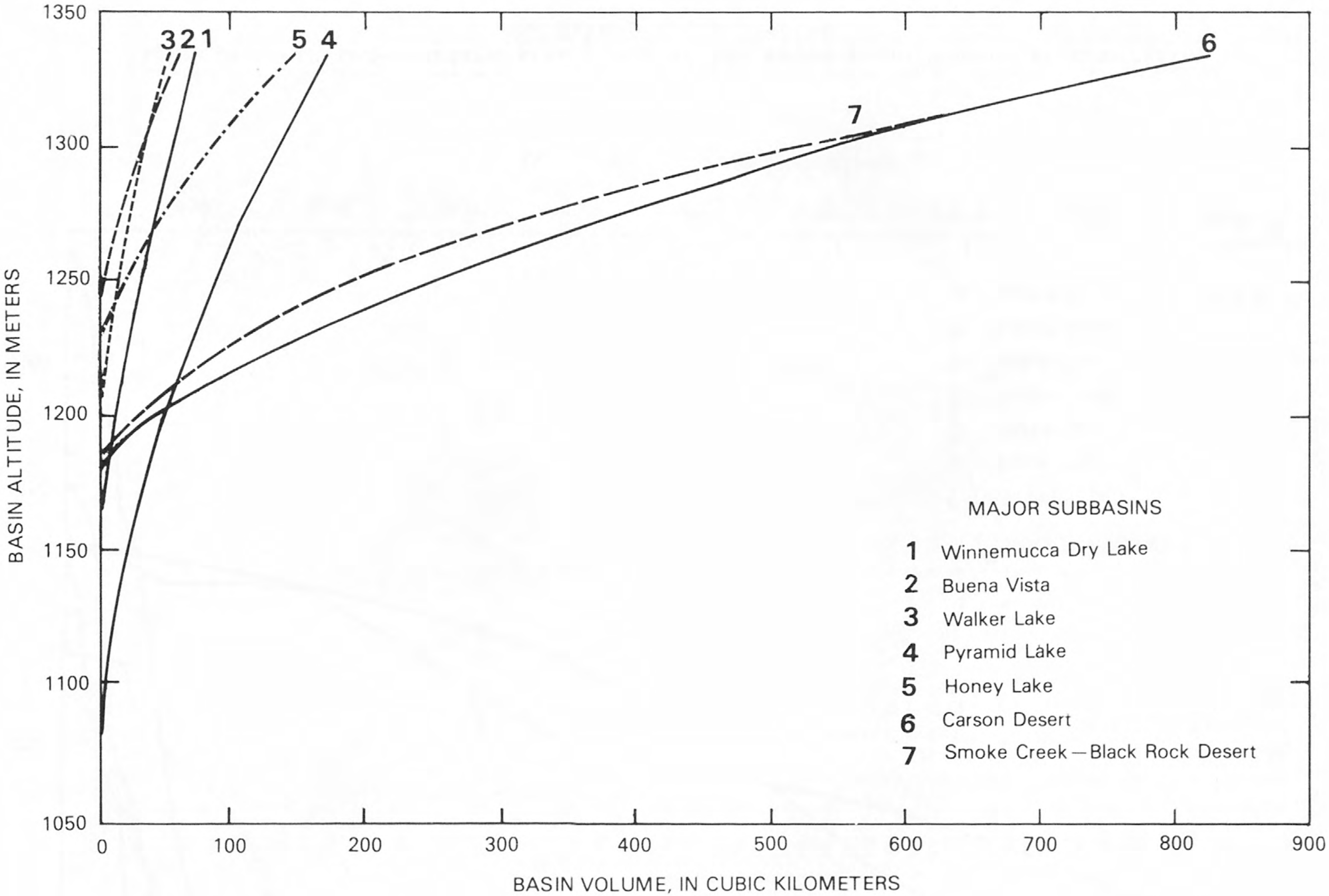

Figure 4.--Altitude-volume plots of the seven major subbasins comprising the Lake Lahontan system.

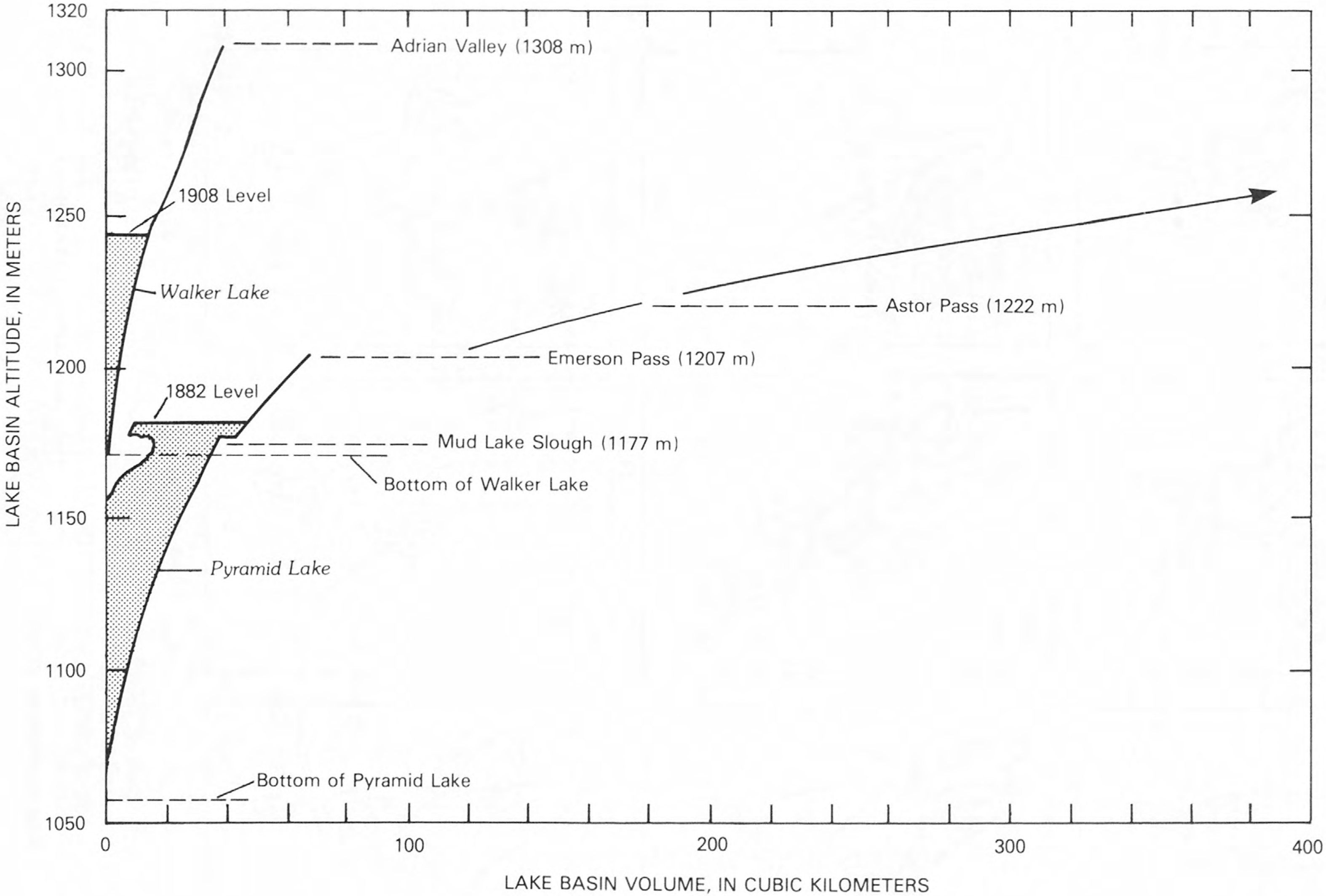

Figure 5.--Altitude-volume plots of the Walker Lake and Pyramid Lake systems. As a lake rises in the Pyramid basin, it spills into a series of basins with relatively large volume-altitude ratios.

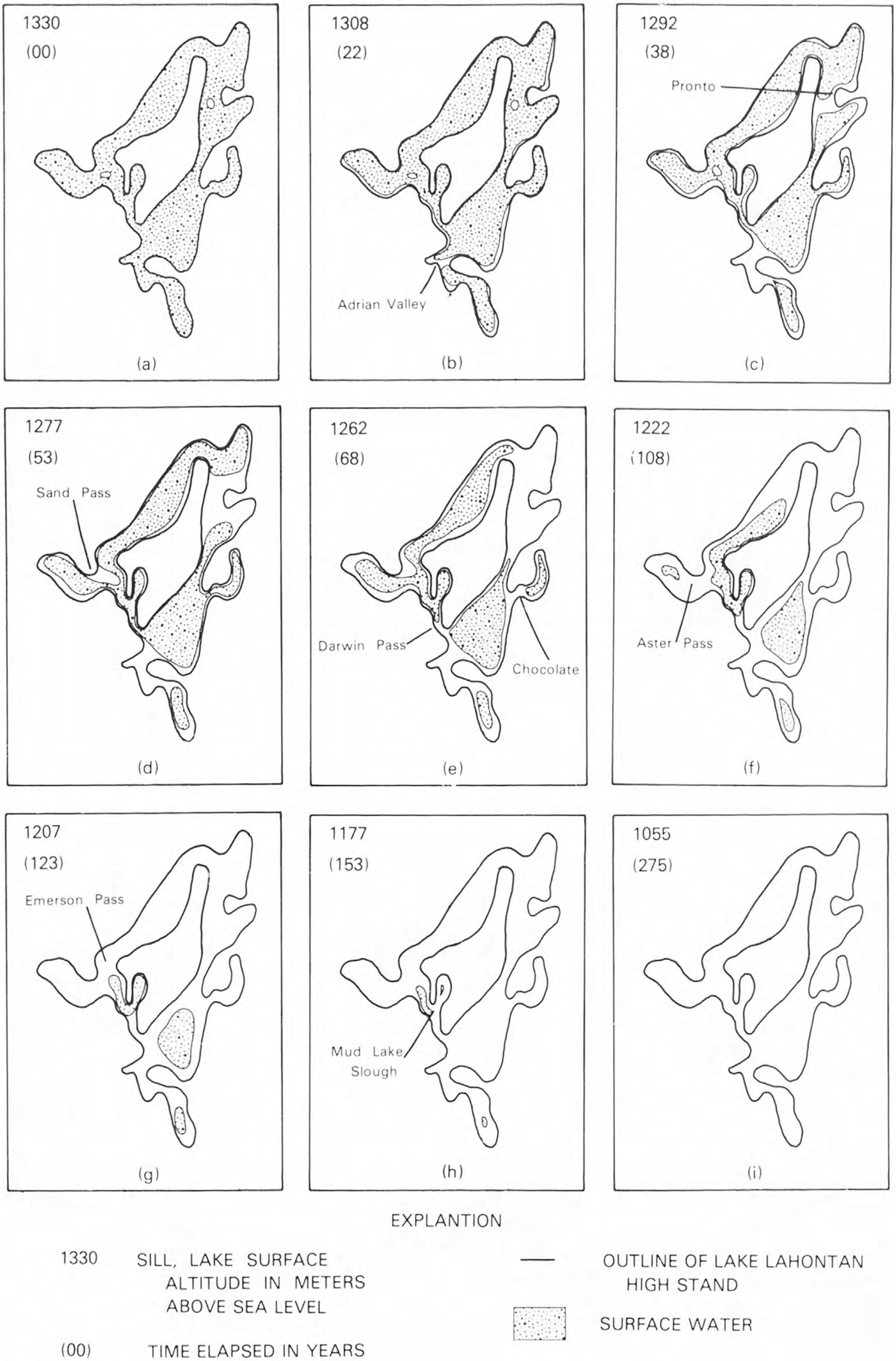

Figure 6.--Surface-area changes of lakes in Lahontan basin caused by a continuous decline in lake level from a 1,300-meter highstand to a 275-meter desiccation, at a rate of one meter per year.

Change in lake level often has been cited as an indicator of climate change. This concept, however, must be applied with caution to the Lake Lahontan system. When Lake Lahontan consists of a single body of water, changes in its surface level inflict changes in the hydrologic balance (climate) of the entire region drained by the Walker, Carson, Truckee, Susan, Quinn, and Humboldt Rivers. However, when Lake Lahontan consists of more than one surface-water body, changes in the surface altitudes of each water body are a function of changes in the hydrologic balance of a subregional-drainage system. Since climate differs from subregion to subregion, changes in lake level in each basin are not expected to occur at the same time or at the same rate.

SUMMARY AND CONCLUSIONS

The last highstand of Pleistocene Lake Lahontan occurred 14,000 to 12,500 years ago. During that time, Lake Lahontan occupied seven topographic subbasins. When the surface level of Lake Lahontan stood at less than 1,308 m in altitude, Lake Lahontan consisted of more than one lake. Changes in surface altitudes of each lake were a function of changes in the hydrologic balance (climate) occurring in each subregional-drainage system.

In this report, the altitudes of the seven primary sills that separate the subbasins, as well as the area and volume of each subbasin as a function of altitude, have been tabulated. These bathymetric data serve as a partial basis for continuing studies of the paleohydrology and paleoclimate of closed-basin lakes located in the Great Basin of the western United States.

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