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Gravity Observations in Northwest Costa Rica

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Introduction

A gravity survey of northwest Costa Rica began in April, 1986 by the U.S. Geological Survey (USGS) as part of an effort to appraise the mineral resource potential of Costa Rica in coordination with the Costa Rican government and the U.S. Agency for International Development.

The principal facts, accuracies, and base stations for about 90 gravity stations are described. Gravity observations were made with LaCoste and Romberg gravity meter G614. Standard gravity corrections were made on all the data. Data were reduced for a density of 2.67 g/cm^3 and referenced to the International Gravity Standardization Net 1971 (IGSN 71) gravity datum described by Morelli (1974).

Gravity Methods

General

Standard gravity corrections were applied to the data and include: (a) the earth-tide correction, which removes the effect of the tidal attraction of the sun and moon, (b) the instrument drift correction, which accounts for changes in the instrument's spring and other instrumental effects, (c) the free-air correction, which accounts for the different elevation of each station, (d) the bouguer correction, which accounts for the attraction of rock material between the station and sea-level, (e) the latitude correction, which takes into account the variation of the Earth's gravity at sea-level with latitude, (f) the curvature correction, which corrects for the Earth's curvature, (g) the terrain correction, which removes the effect of topography, and (h) the isostatic correction, which removes long-wavelength variations in the gravity field and is based on a model for isostatic compensation.

Datum and Base Stations

LaCoste and Romberg gravity meter G614 with a calibration factor, in addition to the factory calibration tables, of 1.00038 was used in the survey. The meter was checked on gravity meter mountain calibration loops (Ponce and Oliver, 1981) prior to and after the field survey. All field data were reduced using the Geodetic Reference System of 1967 (International Union of Geodesy and Geophysics, 1971) and referenced to the IGSN 71 observed gravity datum.

Three base stations, located in San Jose, Puntarenas, and Nicoya were used during the field survey. The base stations are on the IGSN 71 gravity datum and are part of the world relative gravity reference network described by Jablonski (1974). Figure 1 shows all the world relative gravity reference network base stations in Costa Rica. The base station at

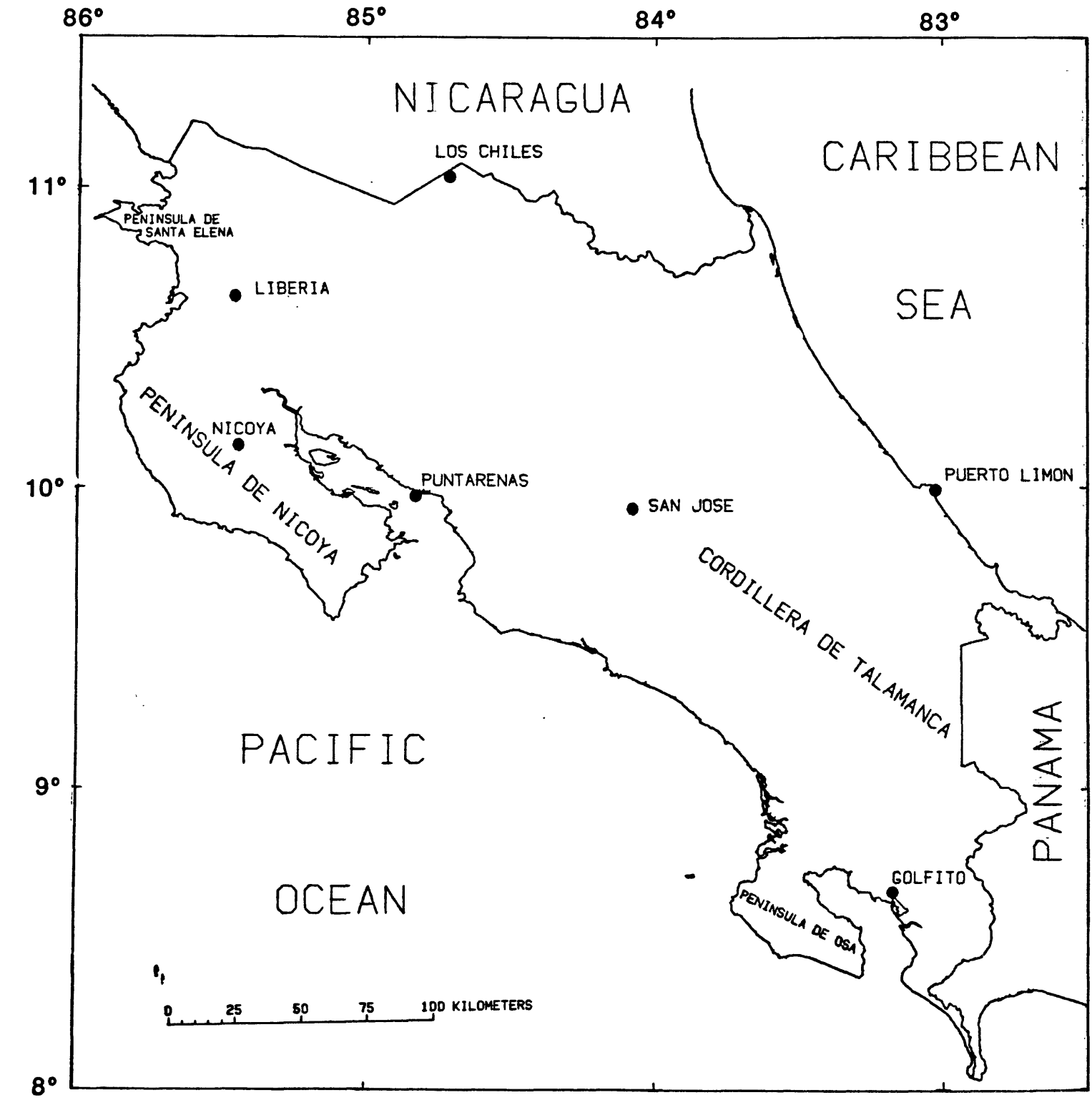

Figure 1.-Index map of Costa Rica showing locations of base stations.

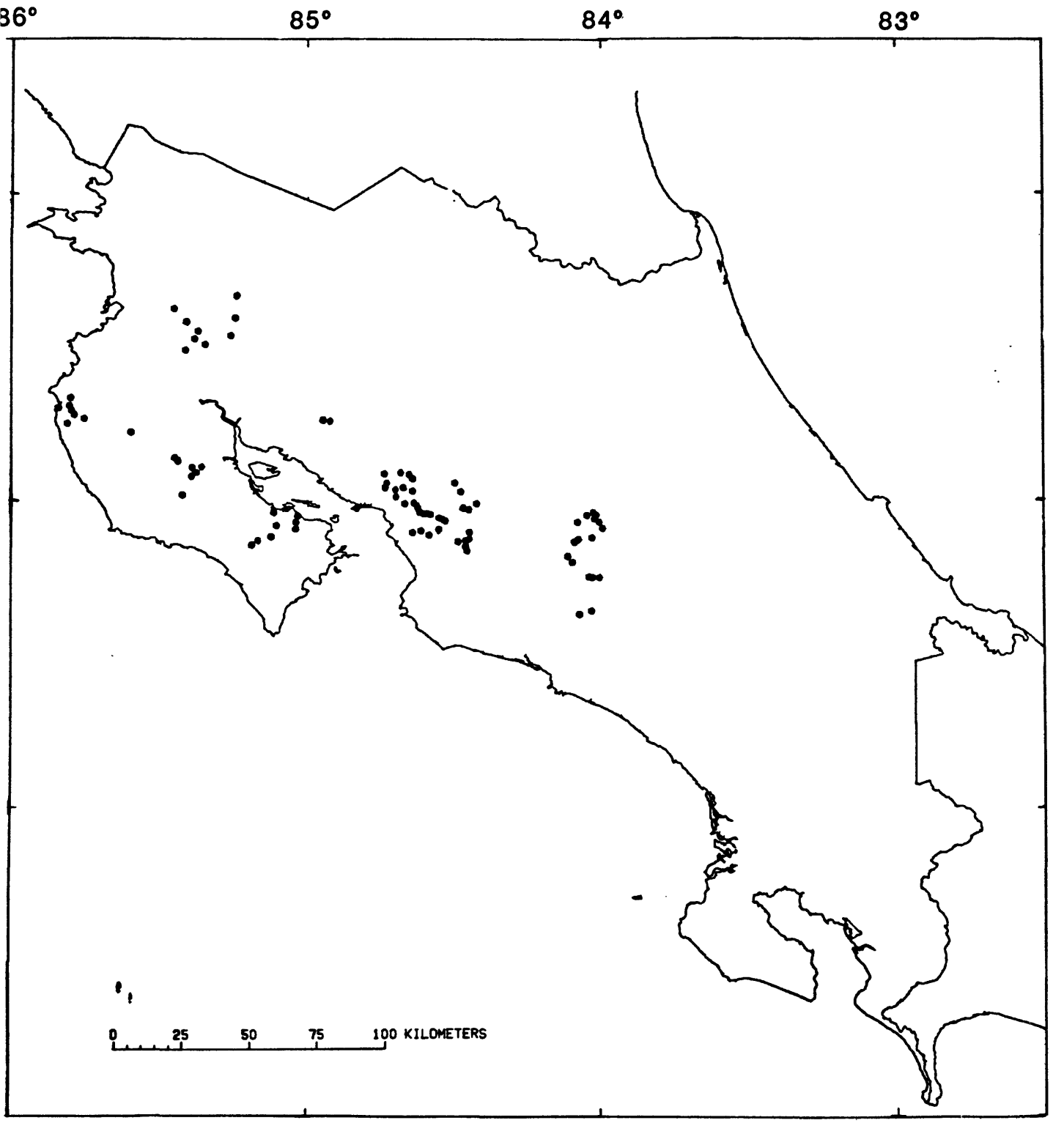

Figure 2.–Index map of Costa Rica showing locations of gravity stations.

Nicoya, which is described as *At the airport, at field level in front of terminal*, is not well described and the terminal has been destroyed. Thus, gravity stations tied to the Nicoya base have a greater uncertainty in observed gravity.

Elevation Control

Gravity measurements were made on bench marks, at *spot-elevations*, or at altimeter survey points. In general, bench marks are considered accurate to about $\frac{1}{2}$ meter, and spot-elevations and altimeter survey points are considered accurate to about 3 meters. A 3-meter uncertainty in elevation results in a Bouguer anomaly uncertainty of about 0.6 milligal, a value much less than the allowable error for most regional gravity studies.

Terrain Corrections

Modern terrain corrections are a three part process: (a) estimation of the field terrain correction, usually to an outer radius of 53 or 68 meters, depending on whether the Hammer (1939) or Hayford-Bowie (1912) system is used, (b) calculation of the inner-zone terrain correction using a transparent template placed on the largest scale topographic maps available, and (c) calculation of the outer-zone terrain correction to a radius of 166.7 km by computer analysis. Because manual terrain corrections are time-consuming, and only a 3-minute average digital elevation model (Glen and others, 1986) is available for Costa Rica, a preliminary estimate of the terrain correction from 0.0 to 166.7 km was made for each station using a computer program by Plouff (1977).

Isostatic Corrections

Isostatic corrections were made on all the data, and are based on Airy-Heiskanen isostatic compensation (Heiskanen and Vening Meinesz, 1958). Isostatic corrections remove long-wavelength variations in the gravity field that are inversely related to topography. The 3-minute digital elevation model was used to calculate the isostatic correction from 0.0 to 166.7 km using a program by Simpson and others (1983) with an assumed upper-crust density of 2.67 g/cm^3, a crustal thickness of 25 km, and a density contrast between the lower crust and upper mantle of 0.4 g/cm^3. Combined isostatic and topographic corrections for regions beyond 166.7 km were derived from published maps of Karki and others (1961) to a distance of 180°.

Data

Locations of all the gravity stations are shown in figure 2. The format of the principal fact data is described in table 1. A four-digit accuracy code, as explained in table 2, has been assigned to each station describing the general location, elevation, latitude, and the observed gravity accuracies. The principal facts are listed in table 3.

References

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Table 1.—*Explanation of principal fact format*

Item	Explanation
STATION NAME	An alphanumeric combination of up to 8 characters used for station identification
LAT	Latitude in degrees and minutes, to 0.01 minute
LON	Longitude in degrees and minutes, to 0.01 minute
ELEV	Elevation, to 0.1 feet
OG	Observed gravity, to 0.01 mGal
AC	Four digit code describing the general location, elevation, latitude, and observed gravity accuracy
FAA	Free-air anomaly to 0.01 mGal
SBA	Simple Bouguer anomaly reduced for a density of 2.67 g/cm^3, to 0.01 mGal
ITC	Inner-zone terrain correction from 0.0 to 0.59 km for a density of 2.67 g/cm^3, to 0.01 mGal (Not used)
TC	Total computer calculated terrain correction from 0.0 to 166.7 km for a density of 2.67 g/cm^3, to 0.01 mGal
CBA	Complete Bouguer anomaly reduced for a density of 2.67 g/cm^3, to 0.01 mGal
ISO	Isostatic anomaly based on Airy-Heiskanen compensation, to 0.01 mGal

Table 2.–*List and explanation of accuracy codes used in this report*

Code	Explanation	Elevation accuracy (ft)	Latitude accuracy (min)	Distance accuracy (ft)	Approximate gravity effect (mGal)
	General location code–1st digit				
B	Level line bench mark	—	—	—	—
V	Vertical angle bench mark (VABM)	—	—	—	—
D	Destroyed or not found reference mark	—	—	—	—
G	Brown spot elevation	—	—	—	—
C	Contour line interpolation	—	—	—	—
A	Altimetry, good control	—	—	—	—
	Elevation code–2nd digit				
1	On bench mark	0.2	—	—	0.01
2	Near bench mark	0.3	—	—	0.02
4	VABM and black map elevation	2.0	—	—	0.10
7	Brown map elevation on 80 ft contour interval map and good altimetry	20.0	—	—	1.20
8	Contour interpolation	40.0	—	—	2.40
	Latitude code–3rd digit				
3	1:24,000- to 1:62,500-scale topographic maps	—	0.04	210	0.05
	Observed gravity code–4th digit				
2	Multiple observations with LaCoste and Romberg gravity meter	—	—	—	0.02
3	Average LaCoste and Romberg or multiple observations with Worden gravity meters	—	—	—	0.05
4	LaCoste and Romberg observations with small vibrations and average Worden gravity meters	—	—	—	0.10

Table 3.–*List of principal facts of gravity data of Costa Rica*

STATION NAME	LAT deg	LAT min	LON deg	LON min	ELEV ft	OG mGal	AC	FAA mGal	SBA mGal	ITC mGal	TC mGal	CBA 2.67	ISO 2.67
CR SJ	9	56.05	84	4.89	3807.1	977922.36	B132	95.02	-34.83	—	3.47	-32.58	29.13
CR J1C	9	57.82	85	6.90	19.7	978258.12	B133	73.54	72.87	—	1.47	74.33	62.74
CR N1C	10	8.47	85	27.05	400.0	978258.12	C833	103.83	90.19	—	2.16	92.17	76.28
CR CR01	9	56.67	84	1.40	4317.6	977879.27	V433	99.63	-47.63	—	4.03	-44.92	18.68
CR CR02	9	56.02	84	0.45	4459.6	977872.85	V433	106.89	-45.21	—	4.48	-42.06	22.25
CR CR03	9	54.81	83	59.81	4479.3	977879.02	G733	115.53	-37.24	—	4.72	-33.86	31.27
CR CR04	9	52.93	84	1.86	4268.4	977907.54	V433	125.17	-20.41	—	3.99	-17.72	46.75
CR CR05	9	52.60	84	4.68	3938.0	977932.46	D233	119.19	-15.13	—	4.26	-12.11	49.83
CR CR06	9	52.11	84	5.39	4101.0	977927.73	D233	130.04	-9.84	—	4.70	-6.41	54.51
CR CR07	9	49.26	84	6.74	5892.4	977814.94	B133	187.16	-13.81	—	8.57	-6.73	50.15
CR CR08	9	57.29	84	2.99	3953.4	977901.74	D433	87.52	-47.31	—	3.70	-44.86	17.69
CR CR09	9	57.31	84	1.05	4445.5	977867.98	V433	100.04	-51.58	—	4.32	-48.60	14.68
CR CR10	9	57.84	84	1.60	4304.5	977876.64	D433	95.17	-51.65	—	4.08	-48.88	13.92
CR CR11	9	48.11	84	5.80	5187.0	977860.52	V433	166.98	-9.93	—	6.19	-5.17	52.90
CR CR12	9	45.20	84	2.44	5872.7	977806.63	V433	179.04	-21.26	—	7.06	-15.68	44.61
CR CR13	9	45.04	84	1.65	5643.0	977825.74	D233	176.63	-15.83	—	6.01	-11.30	50.12
CR CR14	9	45.08	84	0.34	6099.1	977796.05	D233	189.81	-18.21	—	7.04	-12.67	50.07
CR CR15	9	38.55	84	1.90	4706.0	977885.48	D433	151.68	-8.89	—	6.87	-3.40	50.68
CR CR16	9	37.91	84	4.28	5761.2	977812.20	V433	177.76	-18.74	—	12.07	-8.15	39.87
CR CR17	10	1.88	84	28.52	5055.8	977849.34	V433	136.45	-35.99	—	13.95	-23.46	10.68
CR CR18	10	3.55	84	29.86	3999.3	977930.73	V433	117.61	-18.79	—	6.48	-13.57	20.50
CR CR19	9	58.39	84	26.91	3171.9	977969.46	B133	81.17	-27.01	—	5.09	-23.01	11.32
CR CR20	9	58.78	84	28.02	3303.8	977960.80	V433	84.72	-27.96	—	6.24	-22.84	10.11
CR CR21	9	59.60	84	25.39	2744.8	977999.75	V433	70.66	-22.95	—	3.05	-20.88	17.04
CR CR22	9	53.94	84	26.74	1360.2	978089.81	D233	33.35	-13.04	—	2.39	-11.19	19.62
CR CR23	9	52.64	84	26.84	1076.1	978110.73	D233	28.20	-8.50	—	3.22	-5.73	23.56
CR CR24	9	52.28	84	27.51	984.3	978115.61	B133	24.63	-8.95	—	2.84	-6.51	21.22
CR CR25	9	51.24	84	27.50	1003.9	978119.81	B133	31.20	-3.04	—	3.38	-0.06	26.45
CR CR26	9	50.35	84	27.20	1117.5	978116.73	B133	39.26	1.14	—	3.90	4.59	30.54
CR CR27	9	52.11	84	29.09	711.9	978138.19	D233	21.66	-2.62	—	2.77	-0.15	24.72
CR CR28	9	59.62	84	38.29	764.4	978141.96	D233	26.54	0.46	—	1.82	1.97	20.67
CR CR29	9	59.13	84	37.60	623.4	978148.95	D233	20.51	-0.75	—	1.84	0.83	20.03
CR CR30	9	58.69	84	37.37	764.4	978139.03	V433	24.08	-1.99	—	1.82	-0.49	18.47
CR CR31	9	57.82	84	36.99	711.9	978143.26	D233	23.82	-0.46	—	1.76	1.00	19.46
CR CR32	9	57.59	84	36.15	718.5	978140.60	D233	21.90	-2.61	—	1.81	-1.10	18.42
CR CR33	9	57.66	84	35.52	797.2	978132.94	B133	21.61	-5.58	—	1.91	-4.01	16.60
CR CR34	9	57.42	84	34.77	731.6	978135.46	D233	18.08	-6.88	—	2.02	-5.17	16.38
CR CR35	9	56.78	84	33.07	734.9	978131.81	B133	15.07	-10.00	—	2.35	-7.96	15.62
CR CR36	9	56.55	84	32.42	633.2	978135.40	D233	9.20	-12.39	—	2.65	-10.01	14.43
CR CR37	9	56.19	84	31.77	807.1	978123.93	D233	14.28	-13.25	—	2.45	-11.14	13.90
CR CR38	9	54.54	84	33.08	597.1	978144.55	D233	15.98	-4.38	—	1.92	-2.72	18.17
CR CR39	9	53.43	84	35.13	475.7	978169.41	B133	29.98	13.76	—	1.80	15.35	31.44
CR CR40	9	54.25	84	36.74	344.5	978177.82	B133	25.63	13.88	—	1.50	15.22	29.69
CR CR41	9	53.94	84	38.47	331.4	978184.46	B133	31.19	19.89	—	1.39	21.13	32.50
CR CR42	10	0.87	84	41.94	874.0	978137.28	A733	31.53	1.72	—	2.31	3.66	18.45
CR CR43	10	2.21	84	42.03	716.0	978143.68	A733	22.37	-2.05	—	2.27	-0.06	16.33
CR CR44	10	2.63	84	40.44	1024.0	978119.33	A733	26.78	-8.14	—	2.64	-5.92	13.22
CR CR45	9	59.48	84	40.09	682.4	978151.75	B133	28.68	5.41	—	1.74	6.86	22.66
CR CR46	10	2.00	84	38.58	851.0	978128.01	A733	19.51	-9.51	—	2.31	-7.56	13.64
CR CR47	10	4.36	84	38.55	1548.6	978080.67	D233	36.59	-16.23	—	3.03	-13.81	9.92
CR CR48	10	5.19	84	39.30	1958.7	978059.93	D233	54.01	-12.80	—	3.69	-9.86	13.49
CR CR49	10	5.54	84	40.93	2328.0	978042.61	A733	71.25	-8.15	—	5.02	-4.00	17.32
CR CR50	10	3.55	84	43.88	469.2	978159.86	D233	14.63	-1.37	—	2.53	0.95	16.51
CR CR51	10	2.66	84	44.19	367.5	978168.79	D233	14.45	1.92	—	2.07	3.83	17.87
CR CR52	10	5.31	84	44.36	895.7	978131.93	D433	25.93	-4.62	—	2.99	-2.01	14.87
CR CR53	10	15.81	84	56.87	587.3	978166.04	D233	25.53	5.50	—	2.20	7.45	18.21
CR CR54	10	15.59	84	55.43	803.8	978149.97	D233	29.95	2.53	—	2.45	4.65	17.06
CR CR55	10	7.81	85	26.38	390.4	978263.52	D233	108.67	95.35	—	2.11	97.30	81.52
CR CR56	10	6.59	85	23.44	282.2	978262.11	B133	97.71	88.09	—	1.97	89.93	75.24
CR CR57	10	6.68	85	21.62	213.3	978263.26	D233	92.33	85.06	—	1.79	86.75	73.00
CR CR58	10	5.57	85	22.65	331.4	978262.24	D233	103.00	91.70	—	2.04	93.59	78.72
CR CR59	10	4.86	85	23.57	994.1	978228.80	D233	132.29	98.38	—	2.91	100.88	84.89
CR CR61	10	1.26	85	25.49	2034.1	978170.18	D233	173.38	104.00	—	6.01	109.25	88.94
CR CR62	9	55.90	85	2.34	80.0	978248.56	A734	70.64	67.91	—	1.72	69.59	59.25
CR CR63	9	54.60	85	2.40	200.0	978241.62	A734	75.65	68.83	—	1.68	70.62	59.17
CR CR64	9	55.29	85	6.38	251.0	978249.01	A734	87.49	78.93	—	1.68	80.70	67.51
CR CR65	9	53.00	85	7.42	150.9	978259.61	V434	89.83	84.69	—	2.19	86.81	71.18
CR CR66	9	52.29	85	10.11	147.0	978269.38	A734	99.60	94.59	—	1.96	96.48	78.50
CR CR67	9	51.44	85	11.34	152.0	978274.32	A734	105.44	100.26	—	2.02	102.21	82.52
CR CR68	10	16.80	85	47.42	65.3	978290.03	B134	101.76	98.85	—	2.59	101.40	68.70

Table 3.–*List of principal facts of gravity data of Costa Rica–Continued*

STATION NAME	LAT deg	LAT min	LON deg	LON min	ELEV ft	OG mGal	AC	FAA mGal	SBA mGal	ITC mGal	TC mGal	CBA 2.67	ISO 2.67
CR CR69	10	17.60	85	47.95	95.1	978290.06	D234	102.29	99.04	—	2.58	101.58	68.78
CR CR70	10	18.46	85	48.36	91.9	978279.09	D234	90.56	87.43	—	2.56	89.94	57.19
CR CR71	10	18.03	85	50.61	23.0	978269.14	A734	94.36	93.57	—	2.79	96.35	59.65
CR CR72	10	19.97	85	48.11	45.9	978282.70	D234	89.04	87.46	—	2.38	89.84	58.68
CR CR73	10	15.01	85	48.76	81.0	978293.94	A734	106.21	103.44	—	2.86	106.29	69.78
CR CR74	10	16.06	85	45.43	155.0	978285.63	B134	104.31	99.02	—	2.50	101.46	71.17
CR CR75	10	13.39	85	35.91	285.4	978274.63	B134	106.98	97.25	—	2.55	99.67	79.20
CR CR76	10	37.54	85	27.17	428.2	978187.47	B134	20.35	5.74	—	0.97	6.53	3.85
CR CR77	10	34.97	85	24.65	406.8	978185.02	B134	17.28	3.41	—	0.94	4.17	1.68
CR CR78	10	33.21	85	22.27	374.0	978185.82	B133	15.95	3.19	—	0.88	3.91	1.89
CR CR79	10	31.69	85	22.96	256.0	978199.96	A734	19.81	11.07	—	0.84	11.80	8.28
CR CR80	10	29.40	85	24.84	66.9	978222.92	D234	26.39	24.04	—	0.91	24.92	16.72
CR CR81	10	30.50	85	20.82	328.1	978193.69	D234	20.96	9.77	—	0.82	10.45	7.56
CR CR82	10	32.28	85	15.57	331.4	978187.55	D433	14.17	2.87	—	0.84	3.56	5.48
CR CR83	10	35.70	85	14.72	476.0	978184.66	A734	23.23	6.92	—	1.03	7.74	12.55
CR CR84	10	40.08	85	14.34	1409.0	978123.62	A734	47.40	-0.65	—	1.57	0.35	7.58
CR LEPA	9	57.13	85	1.98	19.7	978249.74	B133	65.51	64.84	—	1.40	66.23	57.02
CR PUNT	9	58.64	84	50.01	12.5	978217.22	B132	31.54	31.12	—	1.07	32.18	34.09