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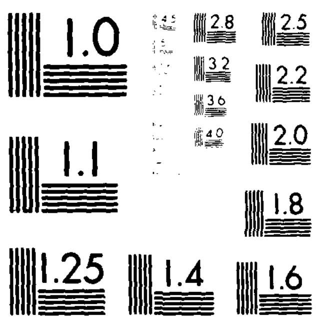


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# PROGRESS IN THE GLOBAL STANDARDIZATION OF GRAVITY: AN ANALYSIS OF THE WOOLLARD AND ROSE INTERNATIONAL GRAVITY VALUES

GEORGE P. WOOLLARD and VALERIE M. GODLEY





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(6) Progress in the Global Standardization of Gravity:

An Analysis of the

Woollard and Rose International Gravity Values,

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(10) George P. Woollard* [redacted] Valerie M. Godley


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## ABSTRACT

The history of improvements in the global standardization of gravity values since the advent of high range gravimeters in 1948 is reviewed. In particular the gravity base values given in SEG special publication International Gravity Measurements (Woollard and Rose, 1963) are evaluated against the most recent set of standardized gravity base values, The International Gravity Standardization Net, 1971 (Morelli et al, 1974). Adjunct IGSN 71 values prepared by the U.S. Defense Mapping Agency Aerospace Center (unpublished) are also used to give a more comprehensive worldwide comparison of values. The results for 787 comparisons of Woollard and Rose (1963) values and IGSN 71 values for the same sites indicate that, in general, there is no difference in gravity standard represented. However, there is a mean absolute datum difference of 14.7 mgal (standard deviation 0.25 mgal). As this value is the same as the difference in the IGSN 71 value for the Woollard and Rose primary base value at Madison, Wisconsin, it corroborates the independent assessment that there is, in general, no difference in gravity standard. However, examination of the data by geographic areas indicates that there are areal anomalous offsets in datum due presumably to undetected tares in the Woollard and Rose values, and also a departure in gravity standard of 0.2 mgal per 1000 mgal in both South America and Europe. As it was possible to establish specific areas in which the Woollard

and Rose values are in apparent error relative to the IGSN 71 values as well as the nature and magnitude of the differences in values, it appears possible to use the more extensive worldwide network of Woollard and Rose base values to extend the IGSN 71 network with, in general, an absolute reliability of the order of ±0.15 mgal. As many of the existing gravity surveys are not tied to IGSN 71 bases, but are tied to Woollard and Rose bases, much of the existing gravity data in the world not on the new IGSN 71 gravity system could thus be integrated into the new international gravity system with sufficient reliability for most purposes. However, more precise gravity values on an absolute basis are required if gravity is to play a significant role in studying global tectonic movements and geodynamic processes.

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## INTRODUCTION

Gravity standardization, although a concern of geodesists for more than three fourths of a century, was a topic of little interest to other earth scientists for many years, and of even less concern to exploration geophysicists until very recently. What has made the standardization of gravity become increasingly important are the following: (1) the recognition of the importance of gravity in understanding regional changes in crustal and upper mantle structure, surficial geology and the distribution and occurrence of all mineral deposits and not just those related to energy; (2) recognition of the fact that we are living on a dynamic earth whose pattern of on-going tectonic horizontal and vertical movements can be detected locally, regionally and globally through secular changes in gravity. Without gravity standardization, the value of gravity in such investigations is limited; but with standardization, gravity becomes a key method for studying such problems. The fact that high precision observations are (1) relatively inexpensive; (2) there exist large bodies of gravity data that can be standardized to useful levels of absolute reliability for such studies and (3) there now exist a world network of gravity standardization bases having an absolute reliability of better than 0.1 mgal, all indicate support and expansion in the role of gravity in both advancing scientific knowledge and applying this knowledge to the benefit of man. This paper represents one step in the process of standardizing the world's gravity data.

## HISTORICAL BACKGROUND ON GRAVITY STANDARDIZATION

The global standardization of gravity started with the Vienna System adopted in 1900, which was estimated to have an absolute reliability of about ±10 mgal. The adoption of the Potsdam reference system in 1909, however, resulted in a -16 mgal correction in the Vienna absolute gravity datum. Other than this action and interconnections of national gravity bases to Potsdam with pendulums having variable reliability, there were few significant advances in the global standardization of gravity until 1947 when a new era in gravity standardization can be said to have started. The significant event in 1947 was the development of the Worden high-range gravimeter, which permitted gravity observations to be made on a global basis with a reliability of better than 1 mgal. This instrument, which Sam P. Worden built for the writer on a "no work--no pay" basis, was tested in 1947 on a semi-global series of leap-frog measurements to evaluate drift stability and repeatability of values (unpublished), and then used in 1948 for an around-the world- series of observations at 33 primary and secondary national gravity bases as well as for the establishment of some 150 new globally distributed gravity bases (Woollard, 1950). These measurements demonstrated that uncertainties in national gravity base values, that at the time were of the order of 2 to 5 mgal (Morelli, 1946; Hirvonen, 1948) and in one case exceeded 30 mgal, could be resolved to better than 1 mgal with gravimeter measurements. This first series of gravity observations with the Worden gravimeter, and the relatively low budget required as compared to pendulum measurements, as well as the significant difference in time required in making a series of world-wide gravity observations, initiated a period of intensive gravity investigations on a global scale. It was attended by continuous improvements in gravity instrumentation (gravimeters, pendulums and absolute gravity apparatus); a significant increase in the numbers of investigators making international and intercontinental gravity measurements and resulted in a marked improvement in gravity standardization. One product of the work done by the writer and his students during the period (1948-1962) was SEG special publication International Gravity Measurements (Woollard and Rose, 1963). This publication represented a compendium of global gravity values and site descriptions for some 100 primary gravity bases established with pendulums and more than 1200 auxiliary gravity bases established with gravimeters. At the time (1963) it represented the most comprehensive and successful attempt to establish a reliable international gravity standard and to cover the world with a network of gravity bases whose values were all on the same datum and gravity standard. This publication also included comparative analyses of not only the national gravity base station values that were in use, but also values being obtained by all other investigators making modern high-range pendulum and gravimeter measurements, with particular emphasis on the differences in gravity standard represented. Although a complete analysis could not be made at the time regarding the absolute reliability of the Woollard and Rose (1963) gravity values, on the basis of comparisons with the values that had been adopted in 1959 by the International Association of Geodesy and the International Gravimetric Bureau in Paris (IBG) for the then designated 34 fundamental international gravity bases, the Woollard and Rose (1963) gravimeter values had a mean overall absolute reliability of the order of ± 0.3 mgal. The actual differences brought out by these comparisons of values, which were possible at 32 of the 34 designated fundamental bases and which covered a range of over 3000 mgal, indicated agreement to better than ± 0.2 mgal at 50% of the sites, and ±0.35 mgal at 75% of the sites.

Another value of the work of Woollard and Rose (1963), moreover, was that it brought into focus problems regarding the international standardization of gravity and their possible solutions. It was this aspect of the work that set the stage for the follow-up World Gravity Standardization Program (Szabo, 1963), whose results are incorporated in the most recent attempt to standardize gravity, The International Gravity Standardization Net 1971 (Morelli et al, 1974). The gravity values given by Morelli et al (1974), referred to here as IGSN 71, incorporate a change of -14.0 mgal in the Potsdam absolute gravity datum and -14.9 mgal in the value adopted for the Bad Harzburg datum used as an alternate for Potsdam during the period (1939-1963) when western observers were not able to make observations at Potsdam. The IGSN 71 values also incorporate an improvement in gravity standard over that which, in general, it had been possible to establish with relative gravity pendulum measurements and early absolute gravity determinations. This improvement resulted from the development of a laser interferometer free-fall absolute gravity apparatus by

Faller, (1965) which was sufficiently portable to permit measurements with the same apparatus at points as widely separated as Fairbanks, Alaska and Bogota, Colombia. It was the observations made with the Faller apparatus between these end points, representing over 4800 mgal change in gravity (Hammond and Faller, 1971), that defined in large measure the IGSN 71 gravity standard Another factor contributing to the reliability of the IGSN 71 values was the redundancy in data available, and some 25,000 modern gravity observations interconnecting the 473 primary gravity bases and their excenters were used in the IGSN 71 adjustments reported by Morelli et al (1974).

The IGSN 71 values are thus on a different absolute datum from the Woollard and Rose and other earlier gravity values, and should be significantly superior in terms of the gravity standard represented, as well as have a higher degree of reliability on a relative basis. The absolute reliability of the IGSN 71 values world-wide as defined by the statistical tests made by Morelli et al (1974) is better than ± 0.05 mgal.

To test the actual degree of improvement represented in the IGSN 71 values of Morelli et al (1974), the writer compared the IGSN 71 values and the Woollard and Rose (1963) values at the same IGB fundamental gravity bases used originally by Woollard and Rose to define the probable absolute reliability of their values. This comparison (presented in the next section) after allowing for the 14.7 mgal difference in the IGSN 71 value for the Madison, Wisconsin base datum used for the Woollard and Rose values showed: (a) no difference in gravity standard from that incorporated in the IGSN 71 values, and (b) that at 58% of the 32 fundamental gravity base sites for which there are comparative data agreement was within ± 0.1 mgal, and that at 80% of the sites the agreement was better than ± 0.2 mgal. These results, substantiated in the next section of this paper, thus indicated the Woollard and Rose values were better than was originally estimated (± 0.3 mgal) and only approximately 0.15 mgal inferior in relative gravity reliability to the IGSN 71 values at better than 75% of the IGB designated fundamental world gravity base sites.

This finding, plus the fact that the IGSN 71 values of Morelli et al (1974) only cover about 550 geographic localities with a heavy emphasis on places in Europe (in contrast to the more extensive world-wide coverage of the Woollard and Rose values) led to this present paper.

## OBJECTIVES ADDRESSED AND METHOD OF ANALYSIS

The primary objectives of the present paper are as follows:

1. To determine if the Woollard and Rose (1963) values do define a gravity standard that conforms everywhere to the absolute standard incorporated in the IGSN 71 values, and if not, where are the departures and what is their magnitude.

2. Are there places where there are significant offsets in datum other than the Madison, Wisconsin base datum offset of 14.7 mgal between the Woollard and Rose (1963) values and the IGSN 71 values, and if so where, and what is the magnitude of the datum shifts.

3. Are there places where there are erratic differences in the two sets of values, and if so what areas are involved and what is the magnitude of the differences.

4. Is it feasible in the light of the above to adjust the Woollard and Rose values to the IGSN 71 gravity standard and datum with a sufficient degree of reliability to in effect extend the global coverage of the IGSN 71 standardization net even though the degree of reliability of the added sites might be 0.1 to 0.2 mgal less than the IGSN 71 values of Morelli et al (1974).

In approaching the above objectives, the gravity standard in each continental area as defined by the Woollard and Rose (1963) gravimeter values at pendulum sites will be examined first. The gravimeter values are used rather than the pendulum values since the quality of the pendulum measurements on a station-to-station basis varied with the area depending on the degree of improvement that had been incorporated in the pendulum apparatus at the time of the observations, whereas the gravimeter measurements were adjusted, insofar as possible at the time, to a single gravity standard. This standard was that defined by the series of pendulum measurements over the North American Rocky Mt. Front calibration range, where three sets of repeat pendulum observations provided a "best" set of gravity standardization values between Point Barrow, Alaska and Mexico City, Mexico.

The comparison of values at all sites in each geographic area to determine the degree of agreement between the Woollard and Rose values and the IGSN 71 values is considered independently from that at the pendulum gravity standardization bases. The reason for making this division of the analysis (the standardization bases versus all bases in an area) is because in order to have a maximum number of comparative values for an area, and hence more comprehensive analysis, IGSN 71 values other than those of Morelli et al (1974) have to be used. The adjunct IGSN 71 values used by the writer are the unpublished values derived by the U.S. Department of Defense Mapping Agency Aerospace Center (DMAAC), which cover about 65% of the Woollard and Rose gravimeter base sites (airports, etc.) that are not related as excenters to the pendulum observation sites. Although, in general, the difference between the IGSN 71 values as determined by Morelli et al (1974) and DMAAC for the same site does not exceed 0.04 mgal, and there is agreement to ± 0.01 mgal for 67% of the 239 comparisons that could be made, it was found that there are systematic differences between the two sets of IGSN 71 values. These change in both magnitude and sign in going from one continental area to another, and in addition there are offsets in datum between the continental areas. These differences in the IGSN 71 values (Figure 1), while not significant in making an overall evaluation of the Woollard and Rose values, were judged to be sufficiently significant in evaluating the gravity standard incorporated in the Woollard and Rose values at the primary (pendulum) gravity standardization bases to restrict the IGSN 71 values used for this purpose to those of Morelli et al (1974). These values aside from there being the "official" IGSN 71 values also have the advantage of including the pendulum base excenter site values used in lieu of the pendulum base values, whereas the DMAAC IGSN 71 values do not.

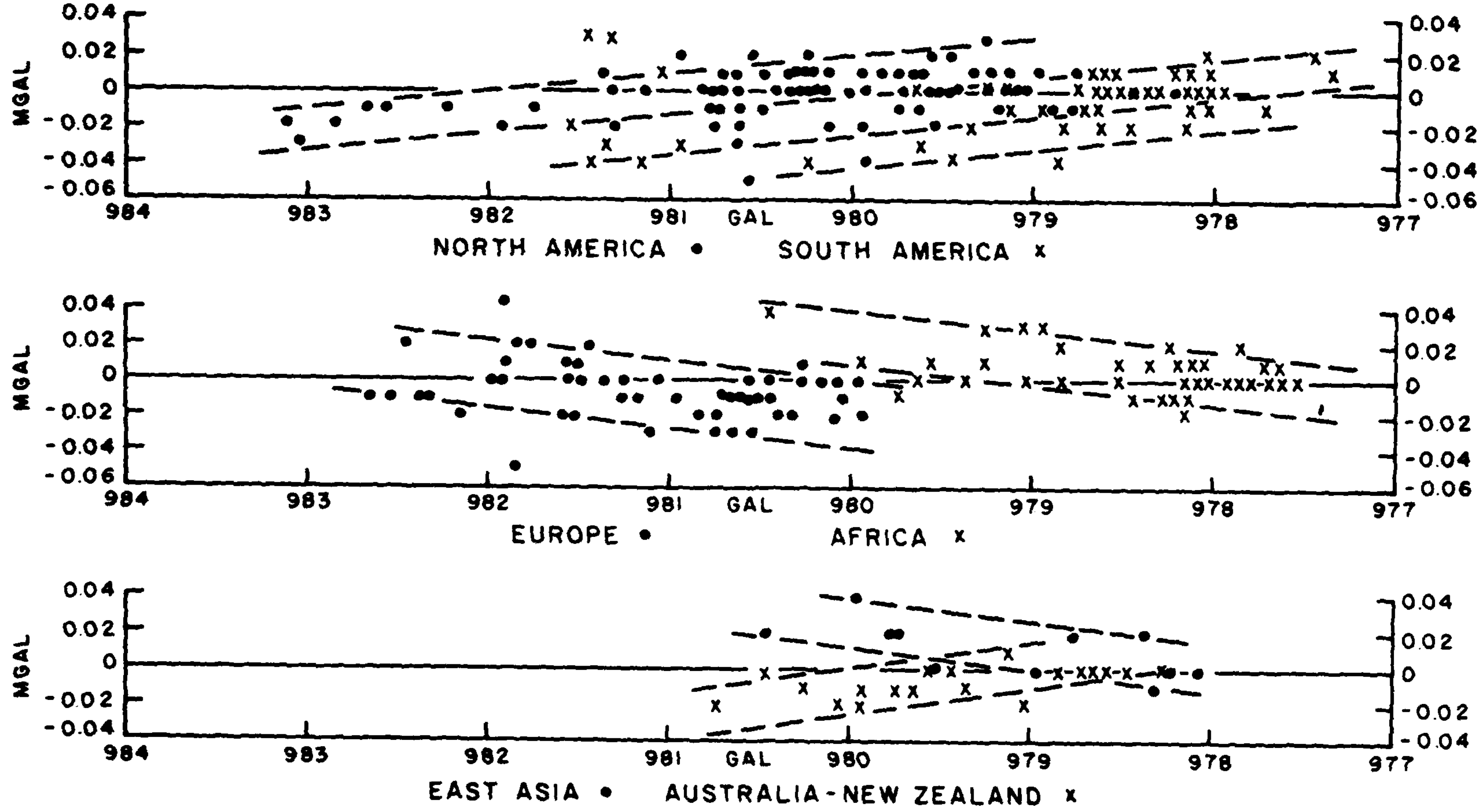



Fig. 1. Comparison of IGSN 71 values as determined by the Defense Mapping Agency Aerospace Center relative to the IGSN 71 values of Morelli et al. (1974).

Because of the extensive number of tables of comparative values involved, these are not included as part of this paper and only graphical representations of differences in values are presented. However, complete tabulations of values by area listed according to the Woollard and Rose (1963) site designation system are available from the SEG office in Tulsa, Oklahoma.

THE EVALUATION OF THE IMPROVEMENT IN GRAVITY STANDARDIZATION INDICATED AT THE IGB FUNDAMENTAL WORLD GRAVITY BASE SITES

As brought out earlier, the absolute reliability of the Woollard and Rose (1963) gravity values was originally defined as being about ± 0.3 mgal on the basis of comparisons with the values adopted for the IGB designated fundamental gravity bases. The datum for the IGB values was that for Bad Harzburg, West Germany (980.1804 gal), which had been adopted as an alternate datum for Potsdam because Potsdam was closed to western observers during World War II and later as a result of the partitioning of Germany. The Woollard and Rose (1963) values, although based on Madison, Wisconsin for datum control were on essentially the same datum as the IGB values since the Woollard and Rose value for Bad Harzburg (980.1803 gal) differs by only 0.1 mgal from the IGB value. As this difference is within the degree of uncertainty in both sets of values, it cannot be regarded as significant. Although earlier attempts to standardize gravity values internationally, such as those of Morelli (1946) and Hirvonen (1948), had not considered Bad Harzburg, they had included quite a number of the other IGB fundamental gravity bases, and since one aspect of the paper is to define the history of improvement in gravity standardization, these values will also be considered in this section along with the IGB (1959) values in determining the degree of improvement in gravity standardization prior to and since the publication of the Woollard and Rose (1963) values. In all cases, the IGSN 71 values of Morelli et al (1974) are used as a standard for comparison.

The comparative values listed in Table 1 are representative of the tables included in this report as Appendix I and Appendix II. Because of the restrictive number of comparisons for the Morelli ( 1946) and Hirvonen (1948) values at IGB fundamental gravity bases, their values for Copenhagen and Stockholm are used to give a more representative set of comparisons for these two sets of adjusted values.

As seen from Table 1, the Morelli (1946) adjusted values show considerable difference from the IGSN 71 values (12.1 to 17.4 mgal). If the difference in datum value at Potsdam (14.0 mgal) is allowed for, the differences range from + 2.0 mgal to - 3.4 mgal. However, the distribution of these differences in values is skewed toward values greater than 1.2 mgal. By coincidence this value (1.2 mgal) corresponds to the degree of apparent reliability for 50% of the 15 comparative values. On the basis of 75% of the values, the agreement is only better than 2.6 mgal.

The Hirvonen (1948) adjusted values show a more normal distribution of differences relative to the IGSN 71 values after allowing for the 14.0 mgal difference in datum. Fifty percent of the values agree to better than 1.2 mgal with the IGSN values and 75% to better than 2.2 mgal. These two early adjustments therefore did not differ a great deal in terms of their overall reliability

Table 1

Comparison of IGSN 71 values at IGB World Fundamental Gravity Bases with Earlier Determined values.

| EURO-AFRICA BASES | (1) IGSN 71 | (2) Morelli 1946 | (3) 1-2 mgal | (4) Hirvonen 1948 | (5) 1-4 mgal | (6) IGB 1959 | (7) 1-6 mgal | (8) Woollard Rose 1963 | (9) 1-9 mgal | (10) 9-14.7 mgal |
|---|---|---|---|---|---|---|---|---|---|---|
| Reykjavik, Natl Base | 982.2650 | | | | | .2785 | -13.5 | .2800 | -15.0 | -0.3 |
| Oslo GW-65 | 981.9126 | .9280+ | -15.4 | | | .9284 | -15.8 | .9272 | -14.6 | +0.1 |
| Helsinki, Natl Base | 981.9006 | .9164 | -15.8 | .9158 | -15.2 | .9152 | -14.6 | .9152 | -14.6 | +0.1 |
| Stockholm, Natl Base* | 981.8314 | .8466 | -15.2 | .8475 | -16.1 | | | .8463 | -15.1 | -0.4 |
| Copenhagen, GW-64* | 981.5430 | .5584 | -15.4 | .5575 | -14.5 | | | .5577 | -14.7 | 0.0 |
| Teddington, GW-67 | 981.1818 | .1960 | -15.2 | | | .1960 | -14.2 | .1966 | -14.8 | -0.1 |
| Bad Harzburg, GW-63 | 981.1655 | | | | | .1804 | -14.9 | .1803 | -14.8 | -0.1 |
| Paris, OBS-A | 980.9287 | .9461* | -17.4 | .9435 | -14.8 | .9437 | -15.0 | .9436 | -14.9 | -0.2 |
| Rome GW-61 | 980.3492 | .3663 | -17.1 | .3663 | -17.1 | .3637 | -14.5 | .3639 | -14.7 | 0.0 |
| Lisbon, GW-110 | 980.0757 | .0885 | -12.8 | .0876 | -11.9 | .0915 | -15.8 | .0903 | -14.6 | +0.1 |
| Madrid, OBS base | 979.9665 | .9830 | -16.5 | .9807 | -14.2 | .9810 | -14.5 | .9812 | -14.7 | 0.0 |
| Beirut , Fac. Med. | 979.6763 | | | | | .6910 | -14.7 | .6909 | -14.6 | +0.1 |
| Khartoum, Camb. Base | 979.2886 | | | | | .3033 | -14.7 | .3033 | -14.7 | 0.0 |
| Dakar, GW-111 | 978.3703 | | | | | .3880 | -17.7 | .3852 | -14.9 | -0.2 |
| Leopoldville, GW-113 | 977.8998 | | | | | .9185 | -18.7 | .9146 | -14.8 | -0.1 |
| Johannesburg, GW-73 | 978.5355 | | | | | .5495 | -14.0 | .5495 | -14.0 | +0.7 |
| Capetown, GW-74 | 979.6327 | | | | | .6472 | -14.5 | .6473 | -14.6 | +0.1 |
| AMERICA BASES | | | | | | | | | | |
| Fairbanks, GW-6 | 982.2317 | | | | | .2452 | -13.5 | .2462 | -14.5 | +0.2 |
| Vancouver, P.O.Base | 980.9207 | | | | | .9370 | -16.3 | .9352 | -14.5 | +0.2 |

+ corrected by 10 mgal for typographical error in Morelli (1946).
* Not designated IGB fundamental bases but included for Morelli (1946) and Hirvonin (1948) comparisons.

Table 1 continued.

| AMERICA BASES (cont.) | (1) IGSN 71 | (2) Morelli 1946 | (3) 1-2 mgal | (4) Hirvonen 1948 | (5) 1-4 mgal | (6) IGB 1959 | (7) 1-6 mgal | (8) Woollard & Rose 1963 | (9) 1-9 mgal | (10) 9-14.7 mgal |
|---|---|---|---|---|---|---|---|---|---|---|
| Ottawa, GW 53-A | 980.6061 | .6210 | -15.9 | .6625 | -16.4 | .6220 | -15.9 | .6208 | -14.7 | 0.0 |
| Madison, GW-3 | 980.3542 | | | | | .3689 | -14.7 | .3689 | -14.7 | 0.0 |
| Washington, U337, Natl base | 980.1043 | .1180 | -13.7 | .1191 | -14.7 | .1190 | -14.7 | .1188 | -14.5 | +0.2 |
| Mexico City, GW-43 | 977.9265 | .7417 | -15.2 | | | .9415 | -15.0 | .9414 | -14.9 | -0.2 |
| Panama, GW-92 | 978.2267 | | | | | .2410 | -14.3 | .2417 | -15.0 | -0.3 |
| Quito, GW-94 | 977.2632 | | | | | .2805 | -17.3 | .2777 | -14.5 | +0.2 |
| Rio de Janeiro GW-109 | 978.7899 | .8020 | -12.1 | | | .8060 | -16.1 | .8047 | -14.8 | -0.1 |
| Buenos Aires, GW 98-A | 979.6900 | | | | | .7046 | -14.6 | .7048 | -14.8 | -0.1 |
| PACIFIC -ASIA BASES | | | | | | | | | | |
| Kyoto, GSI Base | 979.7073 | | | | | .7215 | -14.2 | .7216 | -14.3 | +0.4 |
| New Delhi, GW-5a | 979.1216 | | | | | .1362 | -14.6 | .1363 | -14.7 | 0.0 |
| Honolulu, GW 55 | 978.9384 | | | | | .9526 | -14.2 | .9530 | -14.6 | +0.1 |
| Singapore, GW 102-A | 978.0660 | | | | | .0820 | -16.0 | .0810 | -15.0 | -0.3 |
| Melbourne, GW 83 | 979.9652 | .9880 | -12.8 | | | .9790 | -13.8 | .9797 | -14.5 | +0.2 |
| Christchurch, GW 81 | 980.4943 | | | | | .5095 | -15.2 | .5089 | -14.6 | +0.1 |
| | | | | | | Average without regard to sign | | | | 0.16 mgal |
| | | | | | | Average with regard to sign | | | | +0.012 " |

NOTE: GW prefix is pendulum observation site number designation in Woollard and Rose (1963). Woollard and Rose values (col. 8) are gravimeter values at all sites.

Datum adjustments to IGSN 71 values:
Morelli (1946) -14.0 mgal
Hirvonen (1948) -14.0 mgal
IGB (1959) -14.9 mgal
Woollard and Rose (1963) -14.7 mgal. See column (10) of table.

relative to the IGSN 71 values.

The IGB (1959) adopted values, after allowing for the 14.9 mgal difference in datum at Bad Harzburg relative to the IGSN 71 value for this site, indicate a reliability of better than 0.6 mgal for 50% of the values and 1.1 mgal for 75% of the values. These values, therefore, represent a significant advance in standardizing gravity in the interim period 1948-1959. The Woollard and Rose (1963) values, as indicated earlier, after allowing for the 14.7 mgal difference in datum at the Madison, Wisconsin base relative to the IGSN 71 value for Madison, however, show agreement with the IGSN 71 values to better than 0.1 mgal at 58% of the sites, and to better than 0.2 mgal at 82% of the sites.

As the above differences in values do not give an indication of any bias in sign, the differences with regard to the sign of the correction required to have all values consistent with the IGSN 71 correction for the datum used are shown as distribution plots in Figure 2. Because of the small sample represented in the Hirvonen (1948) values, these are omitted. As seen from Figure 2-A, the datum corrected Morelli (1946) values have a marked bias and the central tendency is centered at - 1.2 mgal, indicating that on average the values would require a correction of -15.2 mgal to agree with the IGSN 71 values rather than -14 mgal, which is the Potsdam datum correction. The IGB values (Figure 2-B) define a central tendency centered at +0.2 mgal, indicating that the mean correction in adjusting these values to the IGSN 71 datum is -14.7 rather than the datum correction of -14.9 mgal that applies to Bad Harzburg.

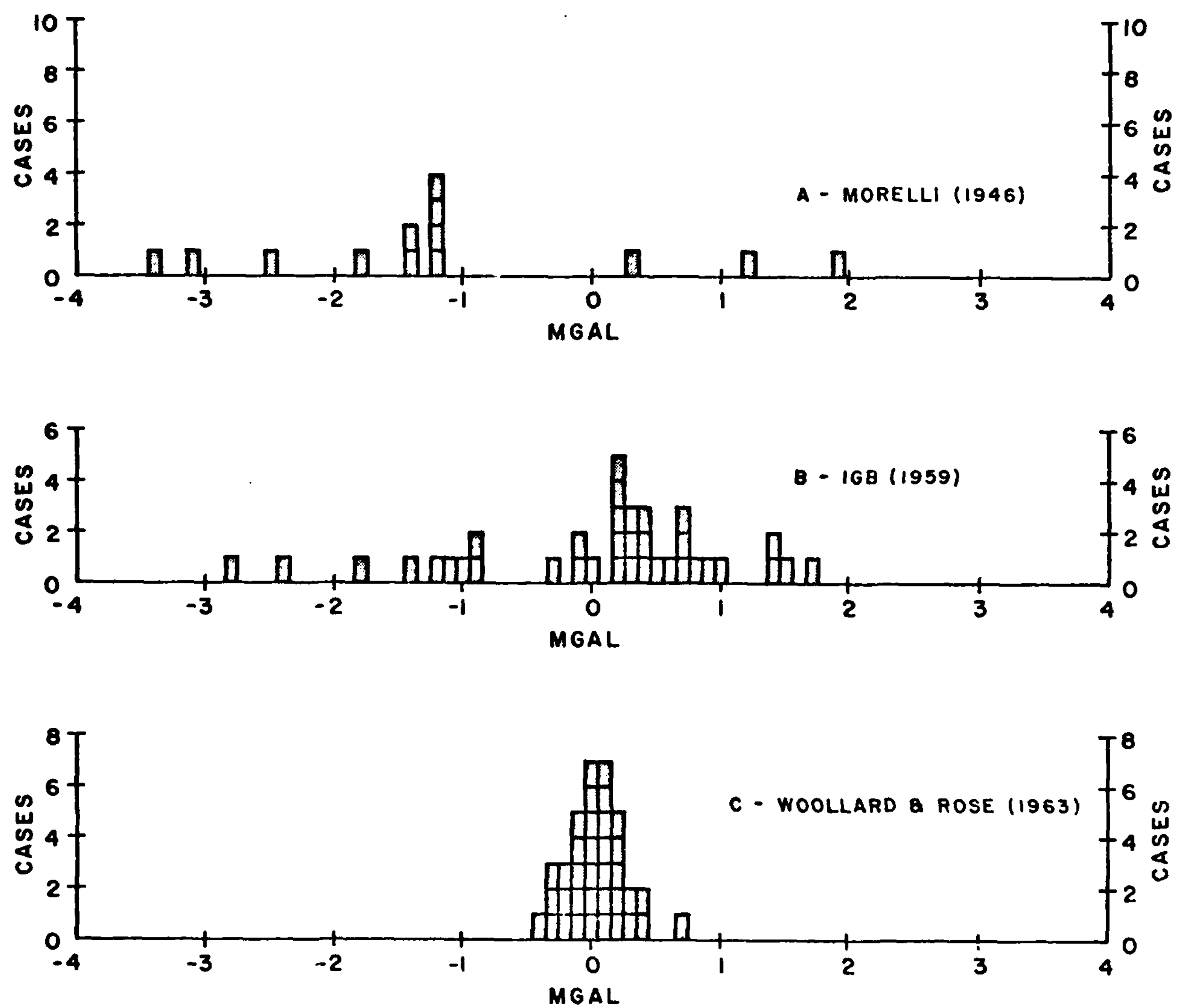



Fig. 2. Distribution plots of differences in datum standardized values of Morelli (1946), the IGB (1959) and Woollard and Rose (1963) and IGSN 71 values at the world fundamental gravity bases.

The Woollard and Rose (1963) datum corrected values (Figure 2-C) in contrast to the Morelli (1946) and IGB values define a near Gaussian distribution centered at + 0.05 mgal, indicating that the median value departs by - 14.65 mgal from the IGSN 71 datum rather than the -14.7 mgal datum difference defined by the IGSN 71 value for the Madison, Wisconsin base. As this degree of skewness in the data has no statistical significance it can be ignored.

In order to examine the gravity standards defined by the above groups of values relative to that incorporated in the IGSN 71 values, the datum corrected differences in values are plotted as a function of absolute gravity in Figure 3. Figure 3-A shows the values of Morelli (1946) and Hirvonen (1948). Both sets of values define essentially the same pattern of differenc relative to the IGSN 71 values: two groupings of values which are separated by about 2.9 mgal. Both sets of values also indicate much the same departure in gravity standard: about 0.66 mgal per 1000 mgal change relative to the standard represented in the IGSN 71 values. The datum corrected IGB values for the world fundamental gravity base sites (Figure 3-B) indicate only a slight difference in standard of about 0.2 mgal per 1000 mgal change from that of the IGSN 71 values. The Woollard and Rose (1963) values (Figure 3-C) define no discernible difference in gravity standard from that incorporated in the IGSN 71 values.

The various comparisons given in Table 1 and graphically portrayed in Figures 2 and 3, therefore, indicate that whereas

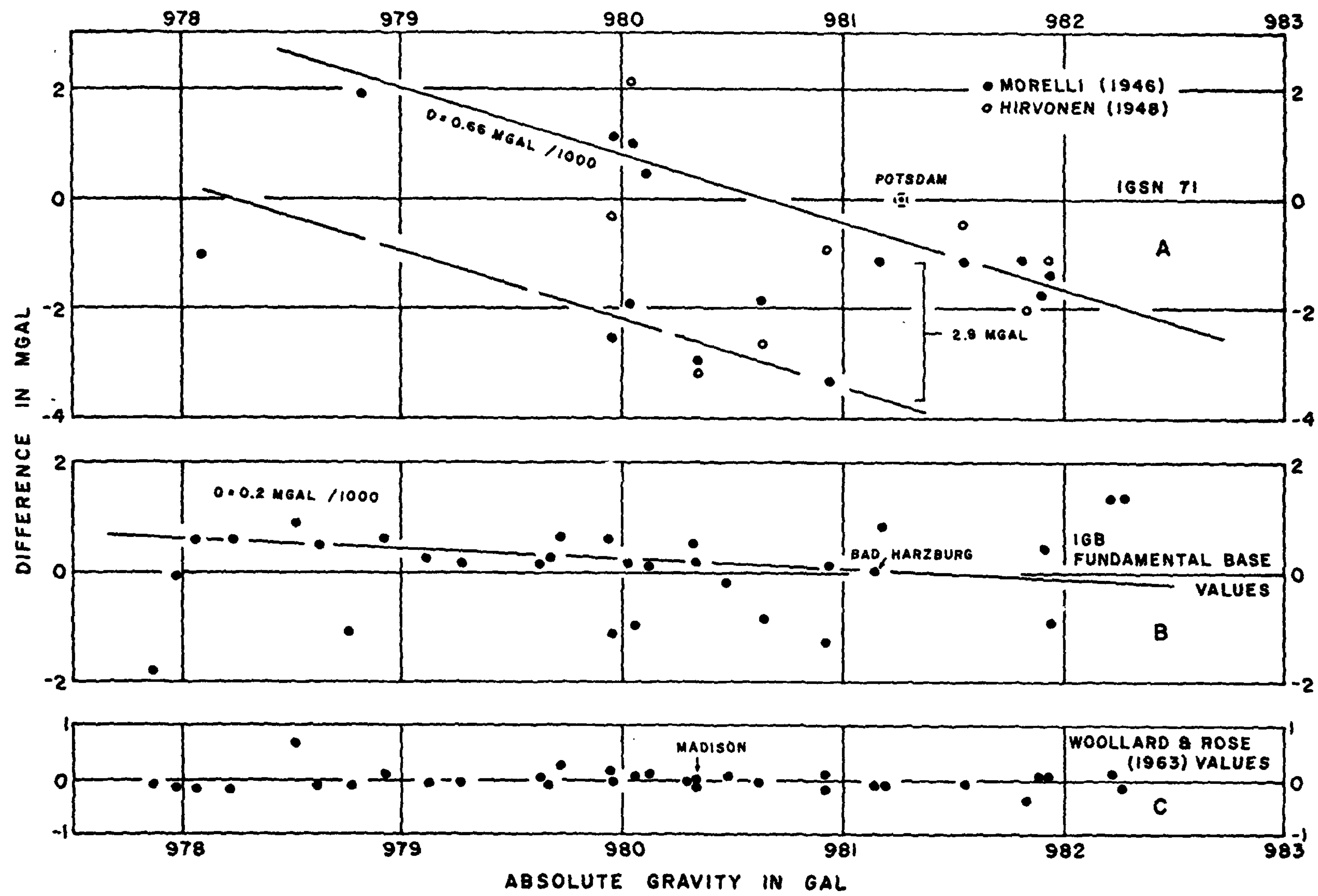



Fig. 3. Differences in gravity standard defined by the datum adjusted value of Morelli (1946), Hirvonen (1948), the IGB (1959) and Woollard and Rose (1963) relative to the IGSN 71 values at the world fundamental gravity bases.

there was a significant improvement in gravity standardization at key gravity bases throughout the world between 1948 and 1959, the most significant improvement was that represented in the Woollard and Rose (1963) values. Subsequent improvement as represented in the IGSN 71 values has been primarily in terms of a revision of the absolute gravity datum values that had been in use, and a reduction in the uncertainty in relative gravity values from about ± 0.15 mgal on average as represented in the Woollard and Rose values to about ± 0.05 mgal on average as represented in the IGSN 71 values. As indicated earlier there is no apparent difference in gravity standard represented in the Woollard and Rose (1963) values and the IGSN 71 values of Morelli et al (1974).

INHERENT LIMITATIONS IN THE WOOLLARD AND ROSE (1963) VALUES RELATED TO INSTRUMENT CALIBRATION

Woollard and Rose (1963) used modified sets of minimum compound quartz pendulum apparatus built by the Gulf Oil Company Research and Development Corporation to make gravity observations which were used as a standard in establishing the overall calibration of the gravimeters they used. The primary series of such pendulum observations in North America included ten sites, other than the Madison, Wisconsin base, distributed between Point Barrow, Alaska and Mexico City, Mexico. Adjunct pendulum measurements were also made along the Pacific coast at Vancouver, Seattle and San Francisco; in the mid-continent region at Madison, Huron, Chicago, Beloit, Tulsa and Houston; and along the Atlantic coast from

Ottawa to Key West. The relative change in gravity along these lines of pendulum measurements which covered over 4700 mgal on the Pt. Barrow to Mexico City series when considered in combination with the laboratory determined calibration of gravimeters provided the gravity standard for most of the Woollard and Rose (1963) gravimeter results.

The limiting factor on the reliability of the calibration of the Woollard and Rose gravimeter data, however, was not in the overall calibration standard defined by the pendulum measurements, but rather pseudo cyclic short to medium range deviations in the readings of the gravimeters. A similar cyclic problem (screw effect) had been early recognized in the use of the Worden gravimeters since reading idiosyncracies could be detected with that instrument's two dial reading system. However, such problems were not recognized as being associated with the LaCoste and Romberg gravimeters until after the publication of the Woollard and Rose (1963) results. What brought this problem into focus was the use of two LaCoste and Romberg geodetic gravimeters simultaneously in 1963 in establishing pendulum site excenter base connections. Repeat measurements with both instruments indicated consistent differences of 0.1 to 0.5 mgal over gravity intervals of the order of 5 to 30 mgal, but with agreement to 0.1 mgal or better over changes of the order of 500 mgal to 3000 mgal. These findings resulted in a series of tests (Woollard, 1964) to establish the cause of the discrepancies, and the source was found to be related to apparent non-periodic deviations in instrument response which had not been detected in the initial laboratory calibration of the gravimeters. As these discrepancies in instrument readings set one of the limits on the reliability of the Woollard and Rose (1963) values, the results of a 32-point laboratory test calibration versus that defined originally using an 11-point laboratory calibration for LaCoste and Romberg geodetic gravimeter LRG-1, which was used in standardizing most of the Woollard and Rose (1963) values, are shown in Figure 4 along with the calibration defined by the pendulum observations. The bottom curve (open point values) represents the original laboratory calibration based on 11 points; this curve parallels closely the top curve (x point values) representing the calibration based on the pendulum observations. Superimposed and lying between these two curves are shown the results (solid point values) obtained for the 32-point laboratory calibration. As seen, there is a non-systematic oscillation in values about a mean curve whose position departs in a near-linear fashion from that of the original calibration and that defined by the pendulum measurements. The effect of these anomalous deviations in the calibration of LRD-1 on the Woollard and Rose (1963) values at the pendulum sites and their excenters between Point Barrow and Mexico City is brought out in Figure 5. In this figure the IGSN 71 values of Morelli et al (1974) are used as a standard for comparison. In order to show also the effect of improvements in gravimeter instrumentation and calibration following the construction of the first LaCoste and Romberg geodetic gravimeter,

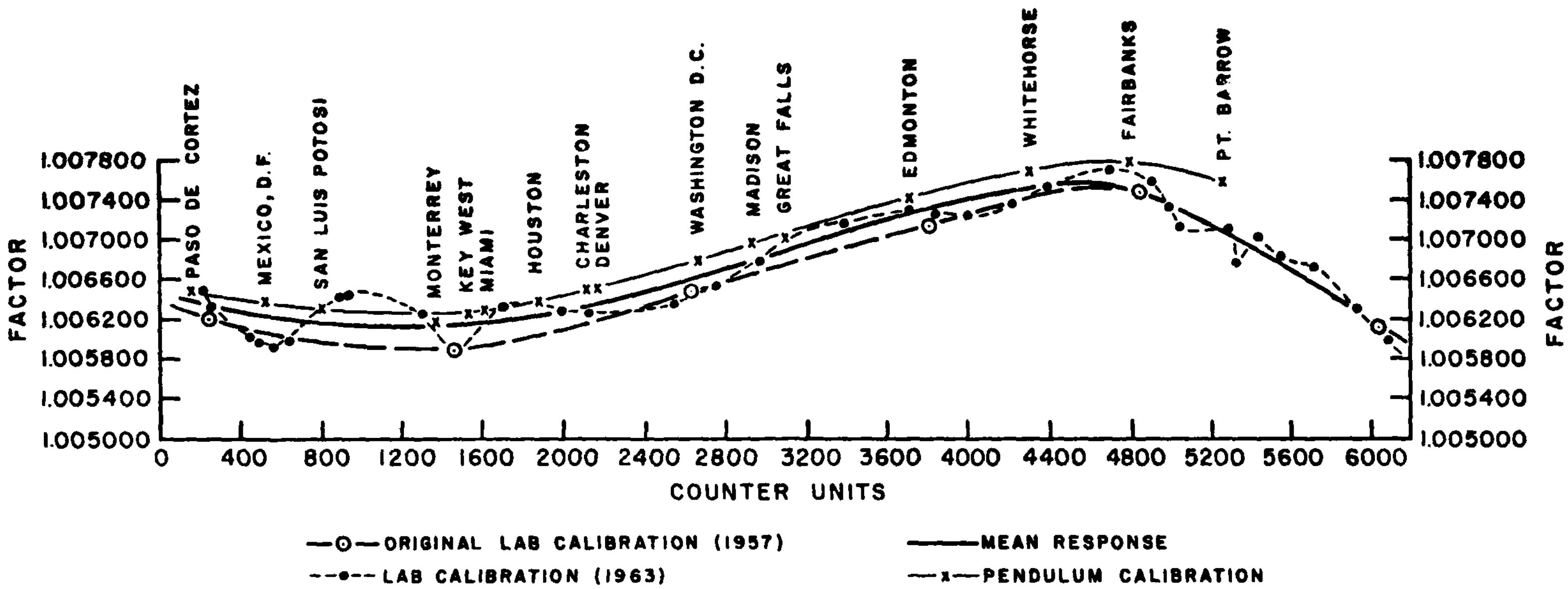



Fig. 4. Comparison of differences in calibration scale factor for gravimeter LRG-1 as defined by an 11-point laboratory calibration (1957), a 32-point laboratory calibration (1963) and pendulum observations Point Barrow, Alaska to Paso de Cortes, Mexico.

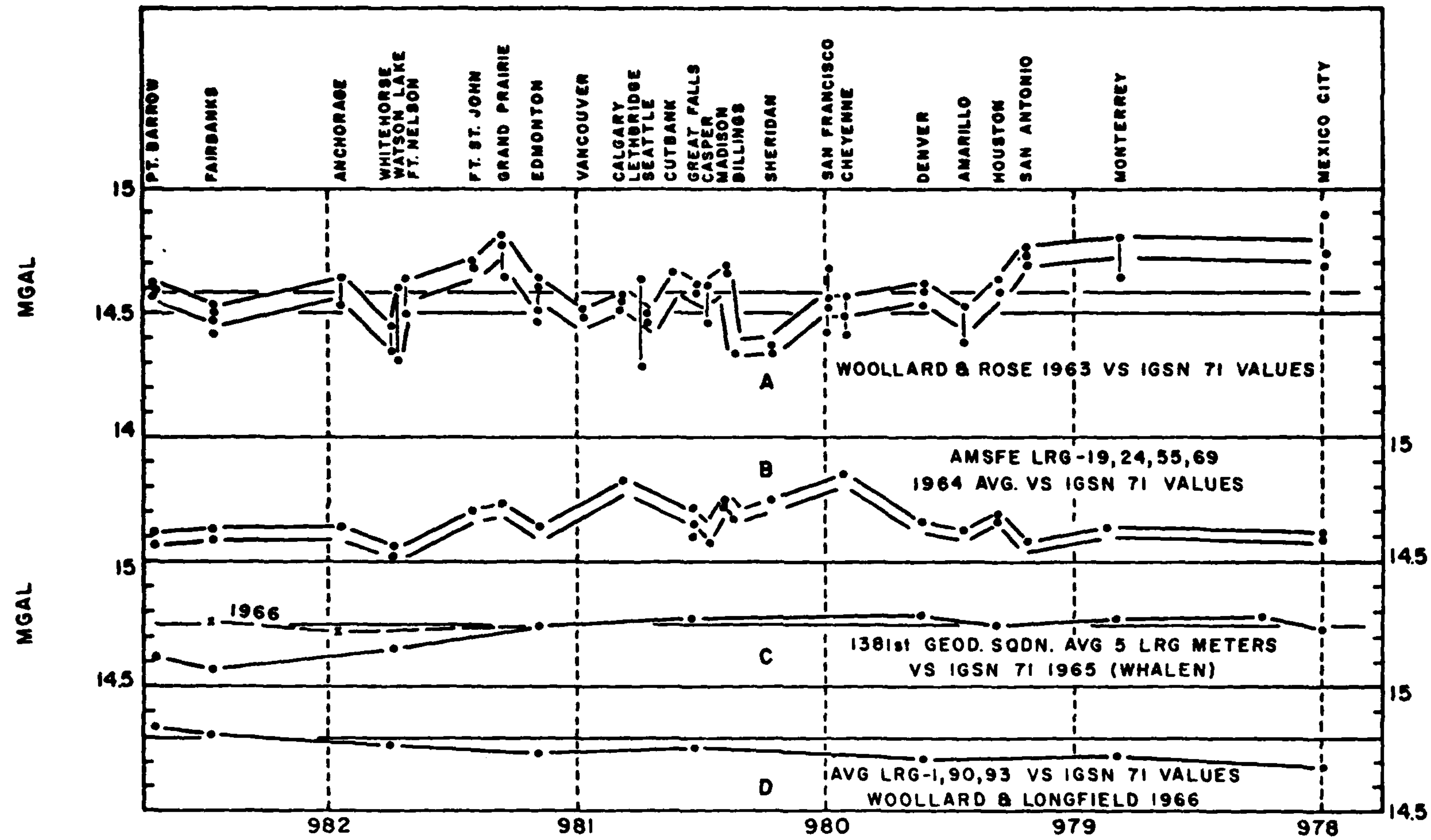



Fig. 5. Comparison plots using the IGSN 71 values of Morelli et al. (1974) as a standard in depicting improvements in gravimeter results obtained with LaCoste and Romberg geodetic gravimeters at the same sites on the North American Rocky Mt. front gravity standardization range over the period 1957-1966.

Figure 5 includes three additional sets of results obtained with LaCoste and Romberg geodetic gravimeters at the same sites at different periods in time. Figure 5-A presents the difference in the Woollard and Rose (1963) values at the pendulum sites and their excenters relative to the IGSN 71 values between Pt. Barrow and Mexico City plotted as a function of absolute gravity. Values at certain off-line pendulum sites (Anchorage, Vancouver, Seattle, Madison, San Francisco and Houston) are also included to give a more complete representation comparable to the changes brought out in Figure 4. A best overall fit to the values would define no overall systematic difference in gravity standard from that incorporated in the IGSN 71 values, and would indicate a datum correction of about -14.57 mgal. However, there is an average of about 0.1 mgal (and occasionally even greater) discrepancy in the pendulum base ties to their excenters, and as is seen, pseudo cyclic deviations in values of the order of ± 0.2 mgal from the mean.

The improvement in the next generation of gravimeters built by LaCoste and Romberg is brought out in Figure 5-B, which presents the average results (unpublished) obtained by the then Army Map Service, Far East in 1964 over the North American Gravity standardization range using four LaCoste Romberg gravimeters. The spread in pendulum base to excenter values at any one site relative to the IGSN 71 values in this plot is, in general, only about 0.05 mgal, and although the short period pseudo cyclic deviations have been reduced to about ± 0.15 mgal, there is a long period deviation of about +0.2 mgal from the IGSN 71 values in the mid-range section.

In Figure 5-C, the average values obtained with five LaCoste gravimeters by the Air Force 1281st Geodetic Squadron (Whalen, unpublished) at most of the same sites in 1965 are shown relative to the IGSN 71 values. These values indicate that the pseudo cyclic deviations in values had been reduced by this time to the point that the uncertainty in values was no more than about 0.04 mgal. Except for the sector north of Edmonton, Canada, no long wave length deviation in values is indicated. That this defect was removed by a subsequent more complete laboratory calibration is indicated by the 1966 values reported by Whalen (unpublished) for Anchorage and Fairbanks.

Figure 5-D shows the values obtained by Woollard and Longfield in 1966 (unpublished) using two later generation LaCoste and Romberg gravimeters and with LRG-1 recalibrated using the 32-point laboratory calibration shown in Figure 4. As is evident, this set of values indicate a difference of about 0.025 mgal per 1000 mgal change in gravity standard from that incorporated in the IGSN 71 values. Since the calibration standard for the set of gravimeter values shown in Figure 5-D was defined by more precise pendulum observations (Woollard and Longfield, unpublished) than were available when the Woollard and Rose (1963) values were published as well as by multiple point laboratory calibrations for each gravimeter, these results raise a question regarding the gravity standard represented in the IGSN 71 values. It appears

significant that the difference in gravity standard depicted is much the same and in the same sign as the difference the writer (Woollard, this volume) finds in the agreement of the IGSN 71 values of Morelli et al (1974) with the 10 absolute gravity determinations used in the IGSN 71 adjustments. However, the small discrepancy suggested in the IGSN 71 gravity standard can be disregarded because it has no significance in evaluating the Woollard and Rose (1963) values since both sets of values appear to be on the same standard as brought out in Figures 3-C and 4-A.

With the above points established concerning the Woollard and Rose (1963) values in general at gravity standardization sites in North America, the data pertaining to each of the four North-South series of pendulum bases established in North America will be considered separately, since it is on an individual basis that the range data have been utilized.

COMPARISONS OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES ON THE NORTH AMERICAN GRAVITY STANDARDIZATION RANGES.

As in Figure 5, the differences in the Woollard and Rose (1963) gravimeter values relative to the IGSN 71 values of Morelli et al (1974) are examined over the range in absolute gravity represented on each gravity range. The center point values on the plots shown in Figure 6 represent the average departure of the Woollard and Rose (1963) values from the IGSN 71 values at each site (pendulum base and its excenters), and the spread in the values is indicated by the error bar. Because there is an apparent offset (tare) in the Woollard and Rose values at and south of

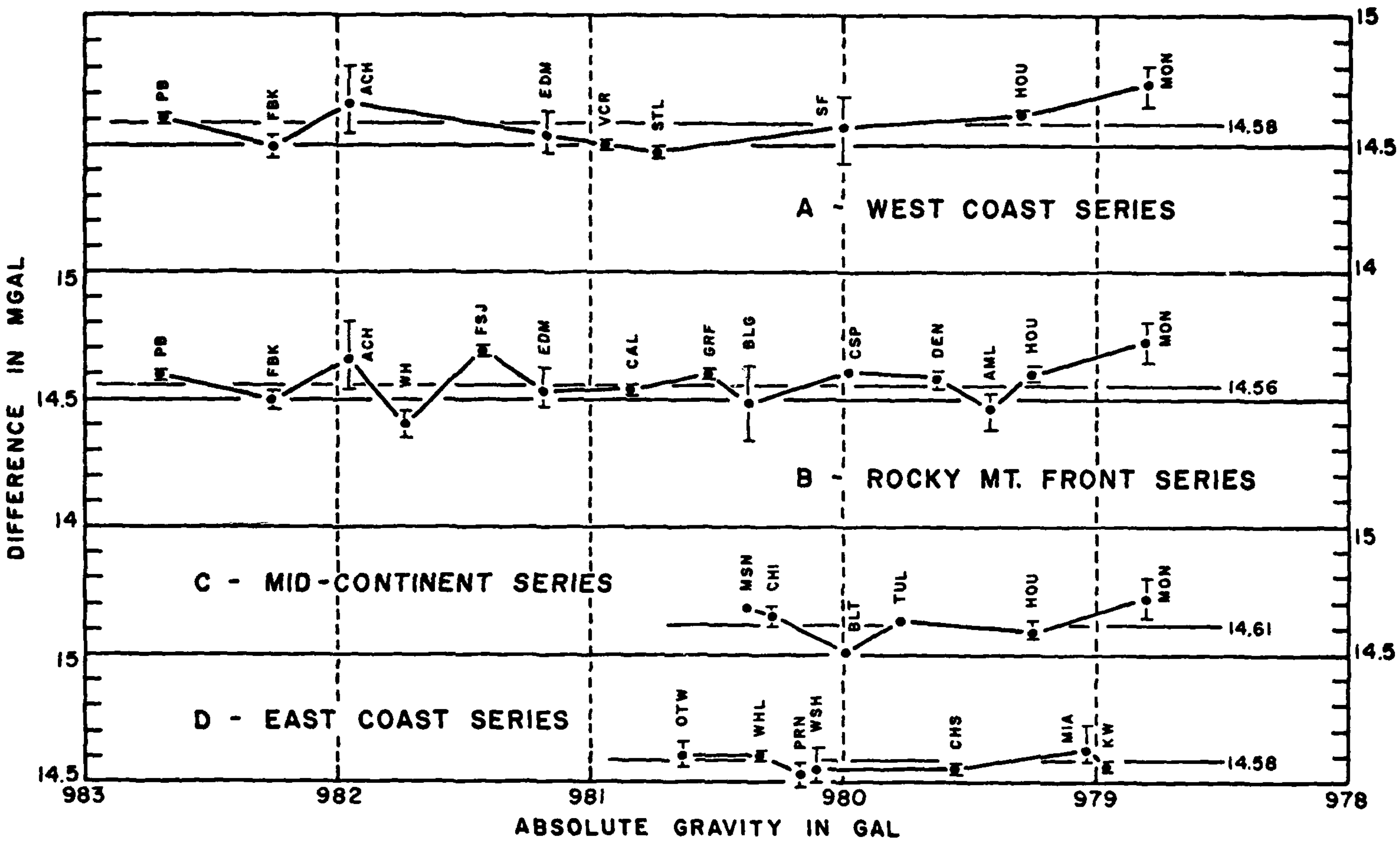



Fig. 6. Comparison of Woollard and Rose (1963) gravimeter values and IGSN 71 values at pendulum ites on each of the North American gravity standardization ranges. A - West Coast Range: PB - Point Barrow; FBK - Fairbanks; ACH - Anchorage; EDM - Edmonton; VCR - Victoria; STL - Seattle; SF - San Francisco; HOU - Houston; MON - Monterrey. B - Rocky Mt. Range: PB, FBK, ACH, EDM, HOU and MON as on A; WH - Whitehorse; FSJ - Fort St. John; CAL - Calgary; GRF - Great Falls; BLG - Billings; CSP - Casper; DEN - Denver; AML - Amarillo. C - Mid- Continent Range: MSN - Madison; CHI - Chicago; BLT - Beloit; TUL - Tulsa; HOU and MON as in A. D - East Coast Range: OTW - Ottawa; WHL - Woods Hole; PRN - Princeton; WSH - Washington; CHS - Charleston; MIA - Miami; KW - Key West.

Mexico City, Monterrey, Mexico is taken as the terminus for each series of observations except the Atlantic coast series that ends at Key West, Florida.

From a casual inspection of the four plots shown in Figure 6, it is clear that there are no overall differences in gravity standard from that defined by the IGSN 71 values on any of the pendulum base lines and very little spread in the absolute datum offset. The datum differences range on average from +14.56 mgal for the Rocky Mt. series of bases to +14.61 mgal for the Mid-Continent series; the West Coast and East Coast series both show a datum offset of about +14.58 mgal. In general, departures of individual site values from the datum offset indicated for a series as a whole, do not exceed 0.1 mgal, and the last series established (the East Coast series) is clearly the best series of measurements.

These results therefore are in good agreement with those indicated at the IGB fundamental gravity base sites as regards agreement in gravity standard with that incorporated in the IGSN 71 values. However, there is a difference as regards the datum offset, which is about 0.1 mgal less (≈14.6 vs. 14.7 mgal) than that indicated by the comparisons at the IGB fundamental gravity bases.

<u>COMPARISONS OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES AT GRAVITY STANDARDIZATION BASES IN SOUTH AMERICA</u>

In Figure 7 three plots similar to those of Figure 6 are shown for the differences in Woollard and Rose (1963) values and

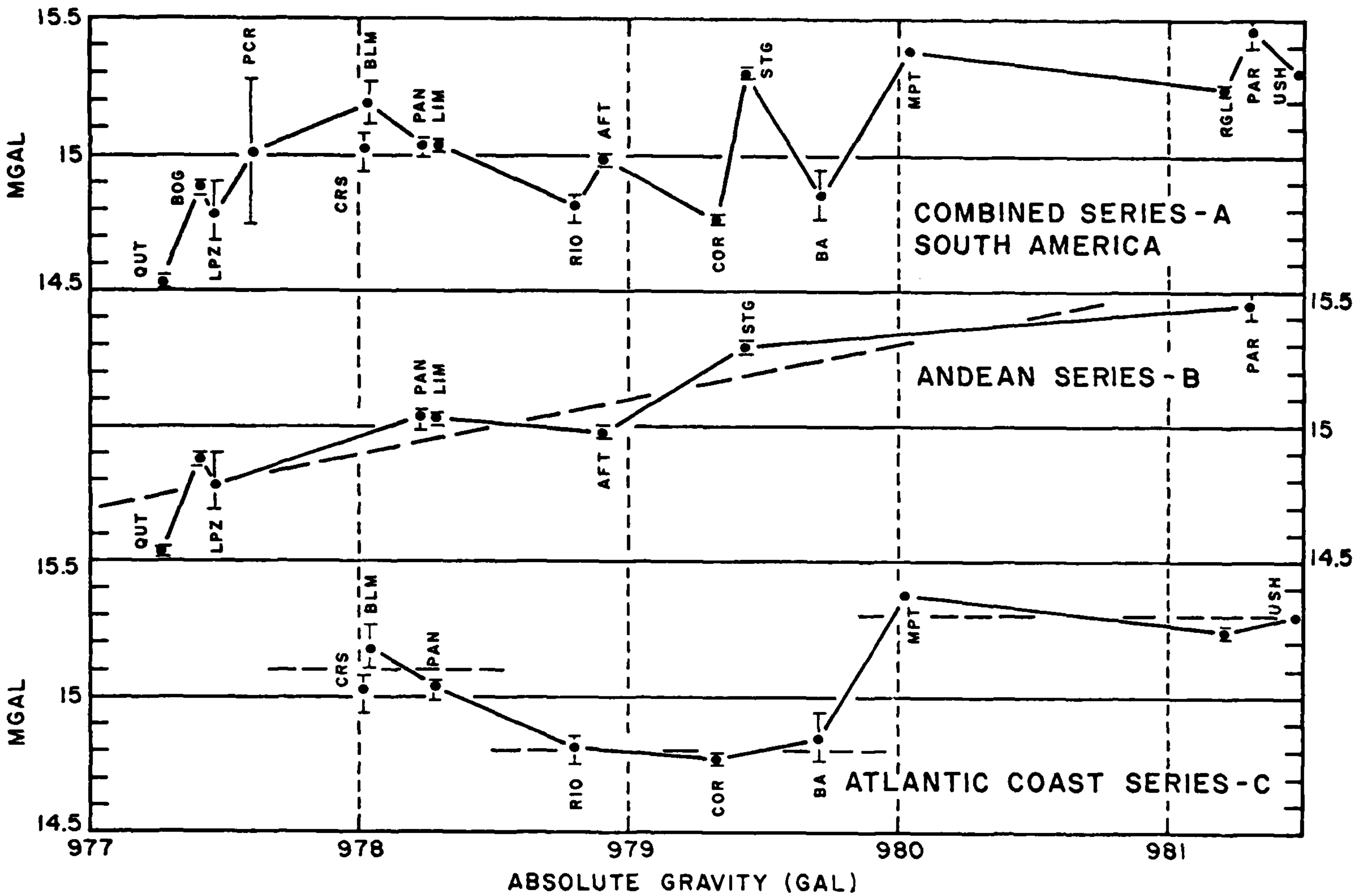



Fig. 7. Comparison of Woollard and Rose (1963) gravimeter values and IGSN values at pendulum sites in South America. A - Combined data for all sites: QUT - Quito; BOG - Bogota; LPZ - La Paz; PCR - Paso de Cortes (Mexico); CRS - Caracas; BLM - Belem; PAN - Panama; LIM - Lima; RIO - Rio de Janeiro; AFT - Antofagasta; COR - Cordoba; STG - Santiago; BA - Buenos Aires; MPT - Mar del Plata; RGL - Rio Gallegos; PAR - Puenta Arenas; USH - Ushuaia. B - Andean Series: Panama to Punta Arenas, Chile. C - East Coast Series: Panama to Ushuaia, Argentina.

the IGSN 71 values of Morelli et al (1974) at pendulum bases in South America. In order to preserve North and South geographic continuity with Figure 6, however, the absolute gravity scale is reversed and the values increase from left to right. In Figure 7-A all of the data are combined into a single plot with an overlap of values from Paso de Cortes, Mexico southward. This plot suggests both a difference in gravity standard from that of the IGSN 71 values and much larger site-to-site departures from some mean value than was brought out by the data for North America.

To resolve the sources of the discrepancies, the data are divided into two groups corresponding to the East-West distribution pattern of the observation sites. Figure 7-B presents the differences for the Andean series of sites from Panama southward to Punta Arenas, Chile, and Figure 7-C for the eastern series of sites from Caracas, Venezuela to Ushuaia, Argentina. As is evident from Figure 7-B, the Andean series of observations is largely responsible for the departure from the IGSN 71 gravity standard suggested in Figure 7-A, and the departure indicated is about +0.2 mgal per 1000 mgal increase in gravity values. In other respects the differences in values are similar to those noted in North America.

In the case of the eastern series (Figure 7-C) it appears that two major tares are involved. One, of about -0.3 mgal, is indicated between Belem and Rio de Janeiro; another, in opposite sign and of about +0.5 mgal, is indicated between Buenos Aires and Mar del Plata. On this interpretation of differences of the

Woollard and Rose values from the IGSN 71 values in eastern South America, no difference in gravity standard is indicated from that of the IGSN 71 values. As it is not likely that two such dissimilar patterns of differences in the Woollard and Rose (1963) values from the IGSN 71 values at the pendulum base sites could have developed in South America, these results will be considered further in examining the data for all sites in South America on an areal basis.

COMPARISONS OF WOOLLARD AND ROSE (1963) VALUES AND IGSN 71 VALUES AT GRAVITY STANDARDIZATION BASES IN EUROPE

Figure 8 shows plots of differences in Woollard and Rose (1963) values and IGSN 71 values at gravity standardization bases in Europe. Figure 8-A is a plot of the differences as a function of the change in absolute gravity from Hammerfest, Norway to Madrid, Spain with an overlap of values into northern Africa. The mean difference in values is about 14.75 mgal, and although there is a scatter of about ±0.2 mgal about the mean, no obvious difference in gravity standard is indicated on an overall basis from that incorporated in the IGSN 71 values. However, there is a suggestion in two sectors (Hammerfest to Helsinki and Paris to Madrid) of a relation similar to that noted in South America for the Andean series of observations. If the distribution of the differences are examined on an individual basis (base sites and excenters as separate observations) as shown in Figure 8-B, a bimodal distribution is indicated. The predominant values occur at 14.7 and 14.9 mgal. These values are substantiated by the distri-

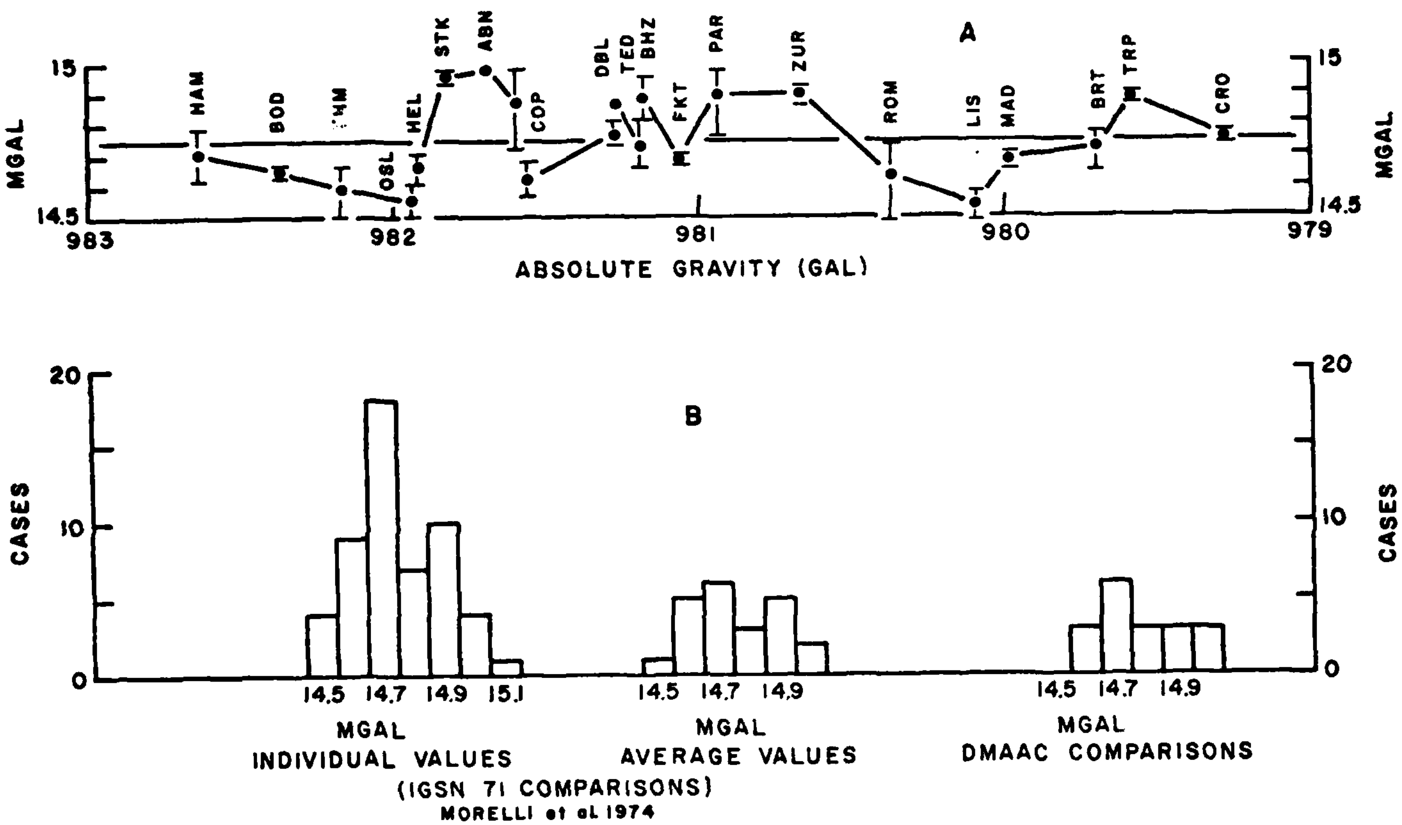



Fig. 8. Comparison of Woollard and Rose (1963) and IGSN 71 values at gravity standardization bases in Europe. A - The differences as a function of absolute gravity. HAM - Hammerfest; BOD - Bodo; THM - Trondheim; OSL - Oslo; HEL - Helsinki; STK - Stockholm; ABN - Aberdeen; COP - Copenhagen; DBL - DeBilt; TED - Teddinton; BHZ - Bad Harzburg; FKT - Frankfurt; PAR - Paris; ZUR - Zurich; ROM - Rome; LIS - Lisbon; MAD - Madrid; BRT - Beirut; TRP - Tripoli; CRO - Cairo. B - Distribution plots of the differences in values.

bution plot for the averaged values for each base. Because attention was called to the difference in IGSN 71 values as derived by Morelli et al (1974) and DMAAC (unpublished), a plot of differences relative to the DMAAC IGSN 71 values at the pendulum bases is also shown. This plot indicates a skewed distribution with a predominant value of 14.7 mgal. All of the distribution plots thus suggest that there are tares of the order of 0.2 mgal in the European values, but it is not clear whether there is any difference in gravity standard.

COMPARISON OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES AT GRAVITY STANDARDIZATION BASES IN AFRICA

In Figure 9 plots of the differences in Woollard and Rose (1963) values and IGSN 71 values at gravity standardization bases in Africa are shown as a function of absolute gravity values. As the minimum gravity value occurs in the mid-continent region near the Equator, 977.5 gal is adopted as a center point of minimum absolute gravity with values increasing in both directions from it in order to have north-south geographic integrity. Figure 9-A is a plot of the differences in values at all base sites in Africa with an overlap of sites into southern Europe. Although there is good continuity with the average relations brought out in Figure 9-A for Europe, there appears to be a major tare separating the data for the northern half of the continent from that for the southern half. The values for sites in the southern sector, also appear to be influenced by a significant difference in gravity standard. That this difference in

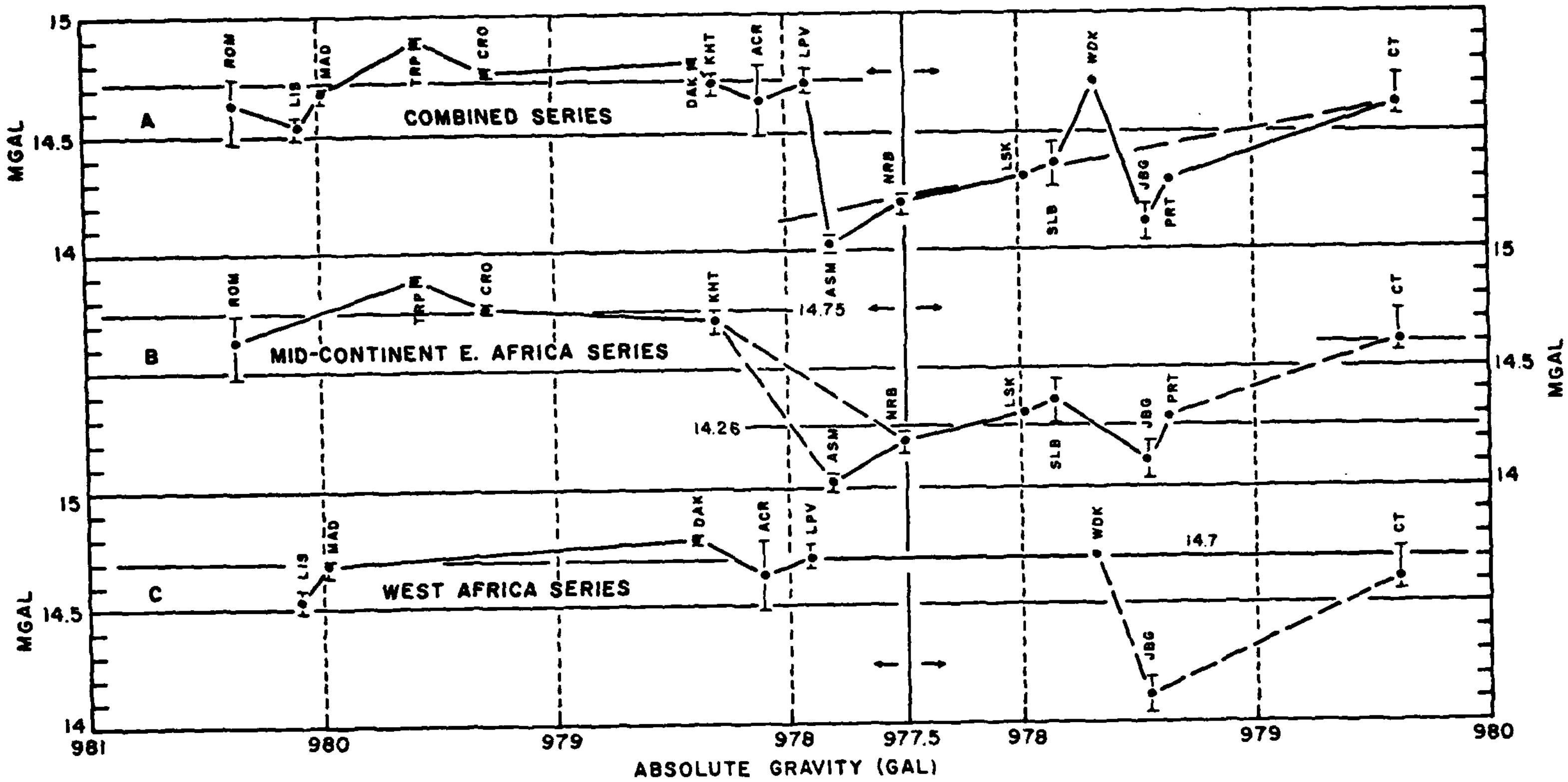
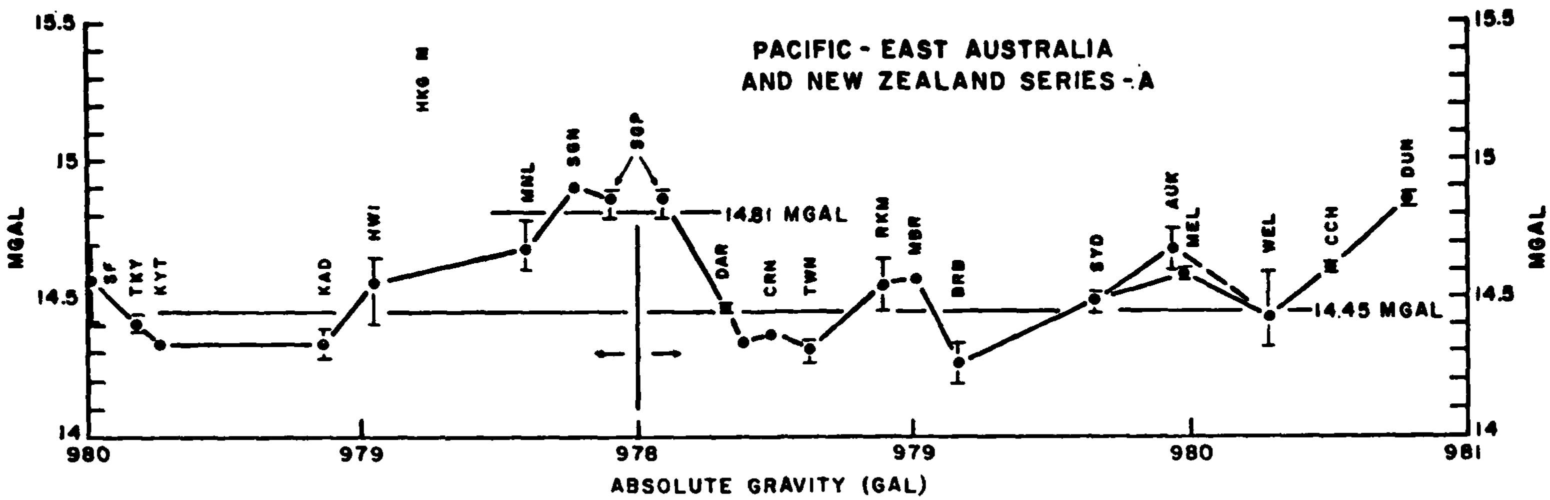



Fig. 9. Comparison of Woollard and Rose (1963) and IGSN 71 values at gravity standardization bases in Africa. A - Combined data for all sites in Africa. ROM - Rome; LIS - Lisbon; MAD - Madrid; TRP - Tripoli; CRO - Cairo; DAK - Dakar; KHT - Khartoum; ACR - Acra; LPV - Leopoldville; ASM - Asmara; NRB - Nairobi; LSK - Lusaka; SLB - Salisbury; WDK - Windhoek; JBG - Johannesburg; PRT - Pretoria; CT - Capetown. B - Mid- Continent-East Africa Series: Rome, Itlay to Capetown, South Africa via Nairobi, Kenya. C - West Africa Series: Madrid, Spain to Capetown, South Africa via Leopoldville (Kinahasa), Zaire.

pattern is a consequence of tares rather than any difference in gravity standard is brought out in Figure 9-B and 9-C, in which the data are subdivided to conform to the East-West geographic distribution of the observation sites. Figure 9-B is for the mid-continent East Africa area, and Figure 9-C is for the West Africa area with an overlap of sites at Johannesburg and Capetown. As seen from Figure 9-B, the mean datum difference relative to the IGSN 71 values is 14.75 mgal from Rome to Khartoum with a tare of about -0.5 mgal between Khartoum and Nairobi and a compensating tare of about +0.4 mgal between Johannesburg and Capetown. That the apparent slope suggested by the data for sites between Asmara and Capetown is fortuitous and a consequence of tares is supported by the data of Figure 9-C. In this plot only the Johannesburg value is seen to be anomalous. All of the other site values show no difference in gravity standard from that of the IGSN 71 values and the datum offset of 14.7 mgal agrees with that for Europe and the northern segment of the East African measurements.

## COMPARISONS OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES AT GRAVITY STANDARDIZATION BASES IN THE PACIFIC SECTOR

Because all gravity ties to the Asia-Australia sector were made from San Francisco via Hawaii, the base value comparisons with IGSN 71 values for these two sites are considered as a part of the group of values for Japan, Southeast Asia, Australia and New Zealand. Figure 10-A shows the differences in Woollard and Rose values relative to the IGSN 71 values plotted as a function



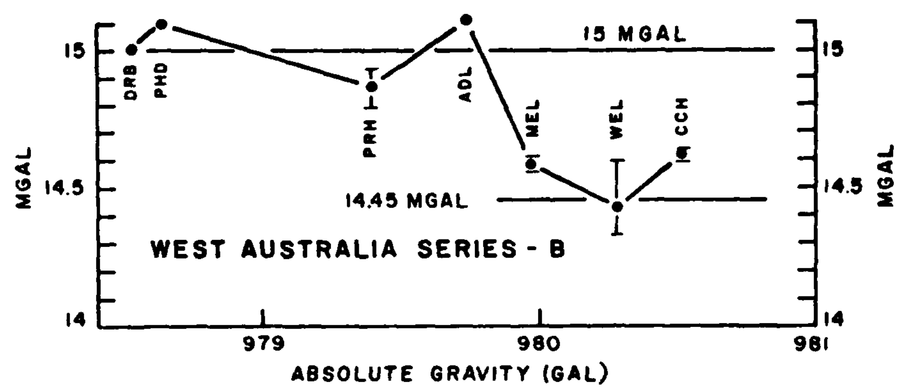




Fig. 10. Comparison of Woollard and Rose (1963) and IGSN 71 values at gravity standardization bases in the Pacific sector. A - Main Series: Japan to New Zealand. SF - San Francisco; TKY - Tokyo; KYT - Kyoto; KAD - Kadena (Okinawa); HWI - Hawaii; HKG - Hong Kong; MNL - Manila; SGN - Saigon; SGP - Singapore; DAR - Darwin; CRN - Cairns; TWN - Townsville; RKM - Rockhampton; MBR - Maryborough; BRB - Brisbane; SYD - Sydney; AUK - Auckland; MEL - Melbourne; WEL - Wellington; CCH - Christchurch; DUN - Dunedin. B - Western Australia Series: DRB - Derby; PHD - Port Hedland; PHR - Perth: ADL - Adelaide: MEL, WEL, and CCH as in A.

of absolute gravity for all sites in the above areas except those in western Australia, which are considered separately since they appear to be affected by a tare. As in the case of Africa, a minimum absolute gravity value (980.00 gal) is taken as a center point in considering sites north and south of Singapore. In Figure 10-A, except for the values at Hong Kong, which appear to be poor measurements; Dunedin, New Zealand, which appears to be affected by a tare; and Manila, Saigon and Singapore, which all appear to be definitely affected by a tare of about 0.36 mgal, all values indicate a datum offset of about 14.45 mgal from the IGSN 71 values with no indication in gravity standard. As shown in Figure 10-B there is an indication of a tare of about +0.53 mgal between Melbourne and Adelaide in proceeding from eastern to western Australia, which increases the difference to about 15.0 mgal for these sites relative to the IGSN 71 values.

## SUMMARY ON WOOLLARD AND ROSE VALUES VERSUS IGSN VALUES AT GRAVITY STANDARDIZATION BASES

Except for the series of Woollard and Rose gravimeter values, from Panama to Punta Arenas, Chile, none of the series of measurements on the gravity standardization ranges appear to be on a different gravity standard from that incorporated in the IGSN 71 values. There are, however, apparent tares ranging from 0.2 mgal to 0.5 mgal that result in datum offsets in some of the series of measurements; notably, the east coast series in South America, the mid-continent East Africa series, and the Pacific series. There are also a few sites that appear to be in significant error, such as Asmara, Ethiopia and Hong Kong.

As the absolute gravity value (980.3689 gal) used by Woollard and Rose for their primary reference base at Madison, Wisconsin is 14.7 mgal high relative to the IGSN 71 value for Madison, (980.3542 gal), all of the Woollard and Rose values should differ approximately this amount from their corresponding IGSN 71 values. The actual mean differences noted by geographic area and percentage of values in each series showing agreement to ±0.1 mgal and ±0.2 mgal or better with the mean for each series are as follows:

World net of IGB fundamental bases: 32 sites

Mean datum difference: +14.7 mgal

Percentage showing agreement to ±0.1 mgal: 58%

Percentage showing agreement to ±0.2 mgal: 82%

North American gravity standardization bases: 40 sites

Mean datum difference: +14.6 mgal

Percentage showing agreement to ±0.1 mgal: 83%

Percentage showing agreement to ±0.2 mgal: 95%

Erratics: Paso de Cortes, Mexico +15 mgal

South American gravity standardization bases:

Eastern series: 12 sites, segmented by tares

(1) Panama, Caracas, Belem: 15.1 ±0.1 mgal

(2) Rio de Janeiro, Cordoba, Buenos Aires: 14.8 ±0.05 mgal

(3) Mar del Plata, Rio Gallegos, UshuaiaL 15.3 ±0.05 mgal

Andean series: 8 sites with different gravity standard

Panama to Punta Arenas, Chile

X = 14.7 + 0.2 (Woollard and Rose value -977.0)

Percentage showing agreement to ±0.1 mgal: 75%

Percentage showing agreement to ±0.2 mgal: 90%

European gravity standardization bases: 22 sites

Mean datum difference: 14.75 mgal

Percentage showing agreement to ±0.1 mgal : 41%

Percentage showing agreement to ±0.2 mgal: 86%

African gravity standardization bases

Western series: 8 sites, Lisbon and Madrid to Capetown

Mean datum difference: 14.7 mgal

Percentage showing agreement to ±0.1 mgal: 75%

Percentage showing agreement to ±0.2 mgal: 87%

Mid-continent-East African series: 1 sites segmented by tares

(1) Rome, Tripoli, Cairo, Khartoum, Capetown: 14.75 ±0.15 mgal

(2) Nairobi, Lusaka, Salisbury, Johannesburg, Pretoria: 14.25 ±0.15 mgal

Erratics: Asmara: 14.05 mgal

Pacific gravity standardization bases: 24 sites segmented by tares

(1) Principal series:

San Francisco, Hawaii, Tokyo, Kyoto, Darwin, Cairns, Townsville, Rockhampton, Maryborough Brisbane, Sydney, Melbourne, Auckland, Wellington and Christchurch:

Mean datum difference: 14.45 mgal

Percentage showing agreement to ±0.1 mgal: 54%

Percentage showing agreement to ±0.2 mgal: 94%

Erratics: Dunedin, New Zealand 14.85 mgal

(2) Manila, Saigon, Singapore: 14.8 ±0.1 mgal

Erratics: Hong Kong 15.4 mgal

Western Australia series:

Adelaide, Perth, Pt. Hedland, Derby: 15.0 ±0.1 mgal

## COMPARISONS OF WOOLLARD AND ROSE (1963) VALUES AND IGSN 71 VALUES ON AN AREAL BASIS

As brought out earlier, a comprehensive worldwide comparison of Woollard and Rose values and IGSN 71 values is possible if the unpublished IGSN 71 values derived by the Defense Mapping Agency Aerospace Center are used to augment the values published by Morelli et al (1974). Although, as shown in Figure 1, the IGSN 71 values derived by DMAAC differ somewhat in datum and standard on an areal basis from those of Morelli et al (1974), the differences in general at any site do not exceed 0.04 mgal. This degree of difference in values is considered to be too small to constitute a significant limitation in using the DMAAC values to evaluate the Woollard and Rose (1963) values at airport and other sites for which there are not Morelli et al IGSN 71 values.

## COMPARISON OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES IN NORTH AMERICA

In order to take cognizance of the fact that a 13 year period is represented in the Woollard and Rose (1963) values;

that different instruments whose calibration was not always well established were used in different areas, and in some areas early measurements could not be repeated with improved instrumentation at other than the standardization bases, the data for North America are subdivided on an areal basis: Alaska, Canada, the United States, Mexico, and Central America and the West Indies. In Figure 11 distribution plots of the differences in the Woollard and Rose values and IGSN 71 values are shown for each of these areas. Figure 11-A presents the data for 58 sites in Alaska. Most of the differences in values (59%) fall within bounds of 14.4 to 14.8 mgal with a central tendency toward an average difference of about 14.55 mgal. In Figure 11-B the data for 57 sites in Canada are shown. In contrast to Alaska, a well-defined median value is indicated for the difference between the Woollard and Rose and IGSN 71 values. The value is 14.6 mgal and 76% of the values do not depart by more than 0.1 mgal from this mean. The data for the United States, which involves 163 sites, are shown in Figure 11-C. In this figure a slightly skewed distribution is indicated with a predominant mean difference value of 14.6 mgal. Agreement to within ±0.1 mgal with this value is indicated for 64% of the values, and 82% of the values agree to within ±0.2 mgal. The differences in values for the 29 sites in Mexico (Figure 11-D), are characterized by wide spread (13.4 to 15.5 mgal). There is no pronounced central tendency toward a dominant difference value, although 59% of the values fall within the bounds of 14.4 to 14.9 mgal. As the average difference in values for this central group

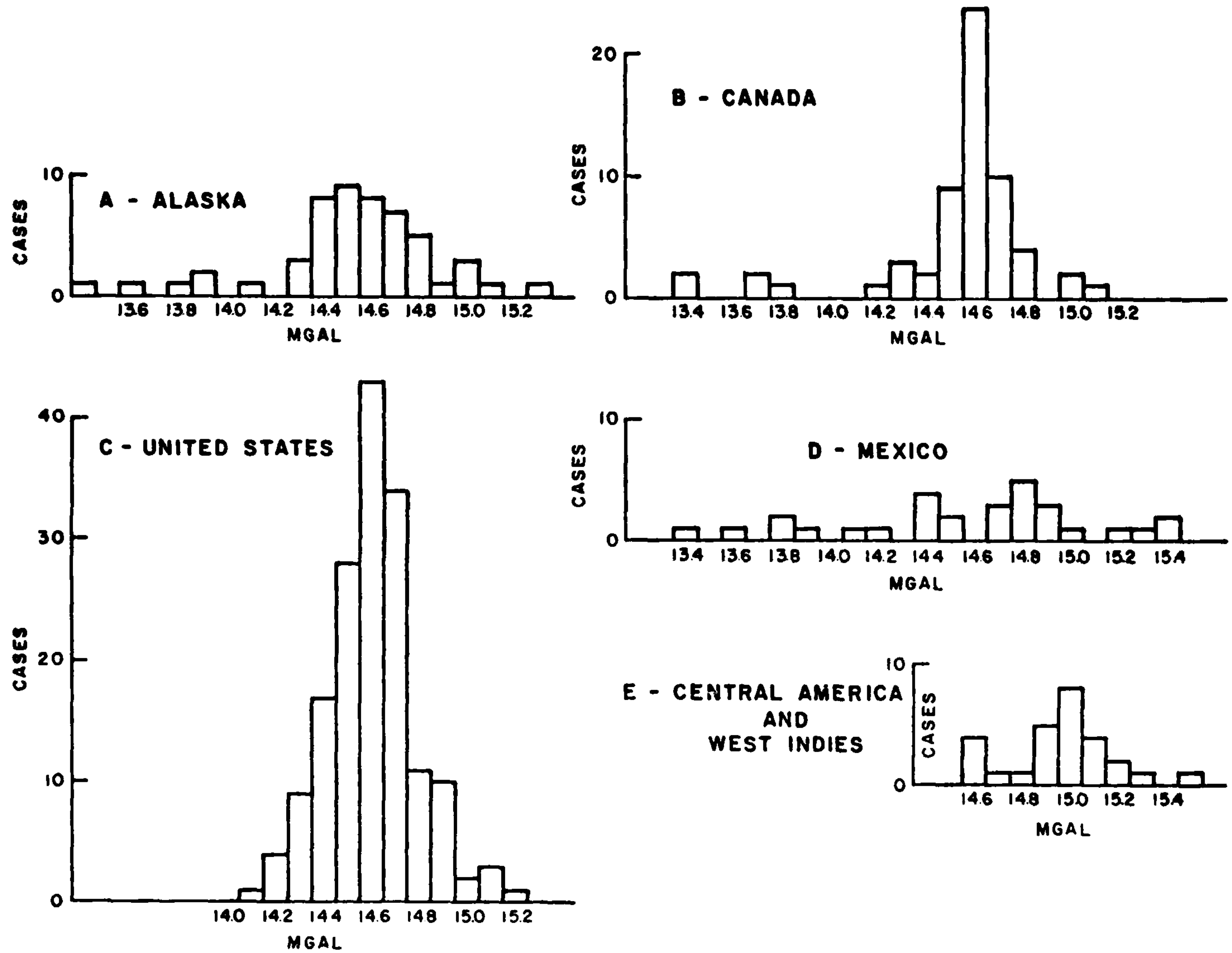



Fig. 11 Distribution of plots of differences in Woollard and Rose (1963) and IGSN 71 values in North America. A - Alaska. B - Canada. C - United States. D - Mexico. E - Central America and West Indies.

of values is 14.7 mgal, and is not significantly different from that indicated for Alaska, the United States and Canada. The comparisons for the 27 sites in Central America and the West Indies (Figure 11-E) indicate a mean difference of 15.0 mgal with 74% of the values differing by no more than 0.1 mgal from the mean. The significantly higher mean difference values for this group of data, 15.0 mgal versus 14.6 to 14.7 mgal elsewhere in North America, can be attributed to the fact that Panama was used as a base in establishing the values. As brought out when considering the gravity standardization base values, the Woollard and Rose value for Panama differs by 15.0 mgal from the IGSN 71 value.

If the above differences in Woollard and Rose and IGSN 71 values in North America are examined in terms of their relations to the change in absolute gravity represented (Figure 12), it is found that the patterns of differences for Alaska and Mexico differ significantly from those for the United States and Canada. In Alaska (Figure 12-A), and Mexico (Figure 12-B) apparent parallel alignments of values having much the same slope suggest that the gravity standard represented departs significantly from that of the IGSN 71 values and that several tares were involved in extending the network of airport base values from the primary bases (Fairbanks and Mexico City). The apparent explanations for the relations indicated in both areas are: (a) the work was done in the late 1940's and early 1950's prior to the development of the LaCoste and Romberg high range gravimeters and was done for the most part with Worden meters which, in addition to having a

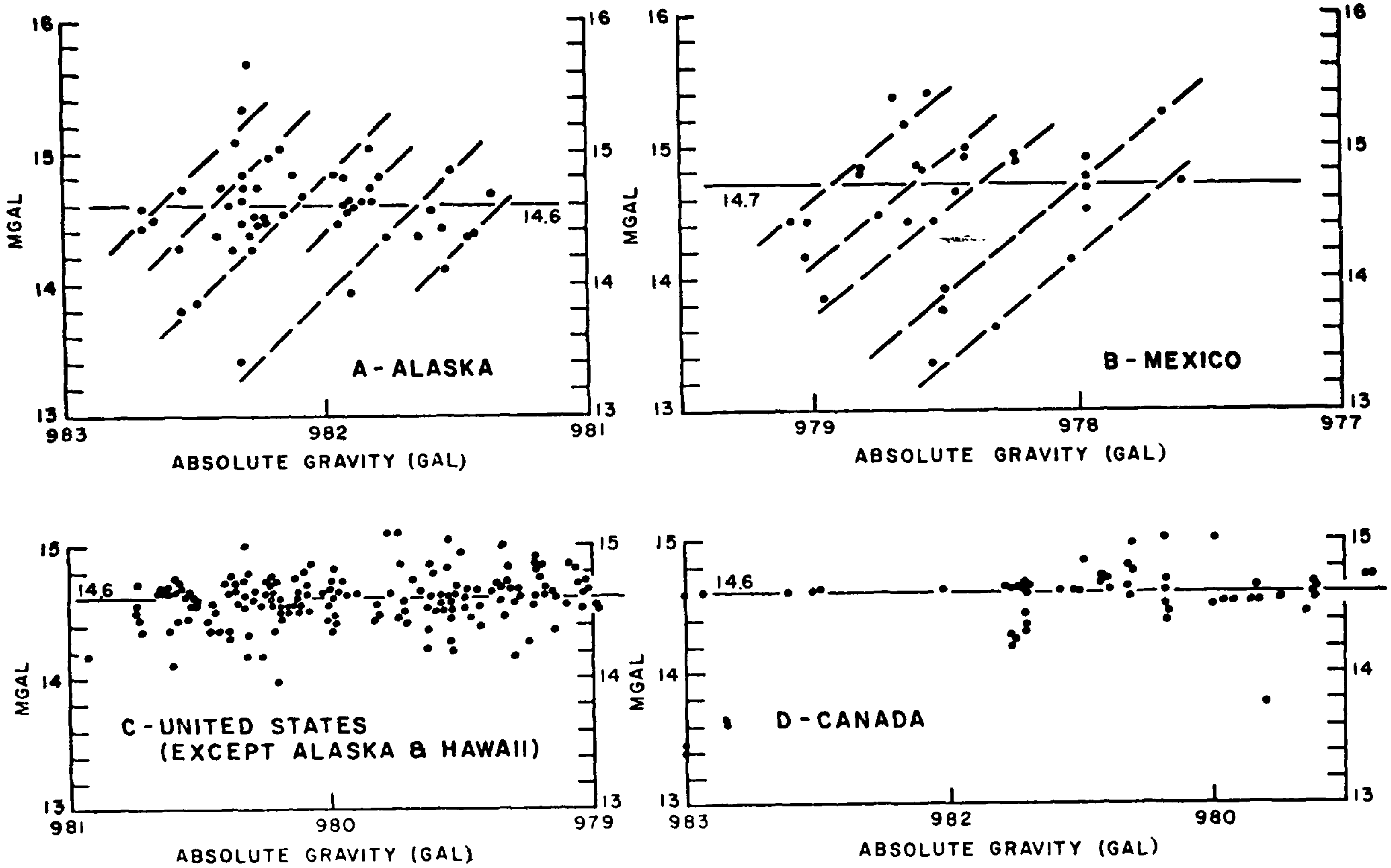



Fig. 12. Relations of dif.erences in Woollard and Rose (1963) and IGSN 71 values in North America to change in absolute gravity. A - Alaska. B - Mexico. C - United States. D - Canada.

high drift rate that varied with type of transportation, were pressure (elevation) dependent and subject to tares from temperature shock as well as mechanical shock; (b) the measurements were made prior to the establishment of the North American pendulum gravity standardization range values and reflect limitations in making tilt table laboratory calibration at a mid-range site (in this case, Houston, Texas) covering the range of the instruments; (c) the measurements were made on a progressive loop basis using advance base sites from one closure loop as a base for the next closure loop, so that any error in a base value on one loop was propagated to the next loop; (d) it was possible to repeat only a few of the observations later with improved and better calibrated gravimeters. In view of the number of adverse factors represented in the data for Alaska and Mexico the pattern of departures in values found is not surprizing.

In Figure 12-C the differences in the Woollard and Rose and IGSN 71 values in the United States are plotted as a function of absolute gravity. Although there is a suggestion that some of the problems indicated in Alaska and Mexico might have expression in some of the values, these represent exceptions. The better degree of agreement for these data in defining no difference in gravity standard from that incorporated in the IGSN 71 values can be attributed to the fact there were two or more sets of values for many sites and that many of the early values obtained with Worden gravimeters at airports (Woollard, 1958), were revised (Behrendt and Woollard, 1961) through repeat measurements using the first LaCoste and Romberg geodetic gravimeter. However, these revisions were not drastic, for of the 39 reoccupations reported by Behrendt and Woollard (1961), 24 (61%) indicated agreement to 0.1 mgal or better, and 33 (85%) indicated agreement to 0.2 mgal or better with earlier Worden gravimeter values. The mean degree of agreement of the Woollard and Rose values with the IGSN 71 values is 14.6 mgal with 82% of the 163 values not departing by more than 0.2 mgal from the mean.

The data for Canada (Figure 12-D), except for five erratics, define a pattern similar to that in the United States. No difference in gravity standard is indicated from that defined by the IGSN 71 values and the mean departure in datum is 14.6 mgal. All the erratics but one appear to be related to a tare caused when the observer was caught in the backwash of a plane and sent tumbling (along with the gravimeter) across the ice in the Canadian Arctic. The IGSN 71 comparative values indicate the tare correction applied in reducing the data was incomplete for these sites.

COMPARISONS OF WOOLLARD AND ROSE (1963) AND IGSN 71 GRAVITY VALUES IN SOUTH AMERICA

Because of the difference in gravity standard brought out in the comparison of Woollard and Rose values at the gravity standardization bases in the Andean region of South America and the tares indicated in the eastern series of measurements, the differences at airport and port sites are considered on a country by country basis. Figure 13-A is the distribution plot of the

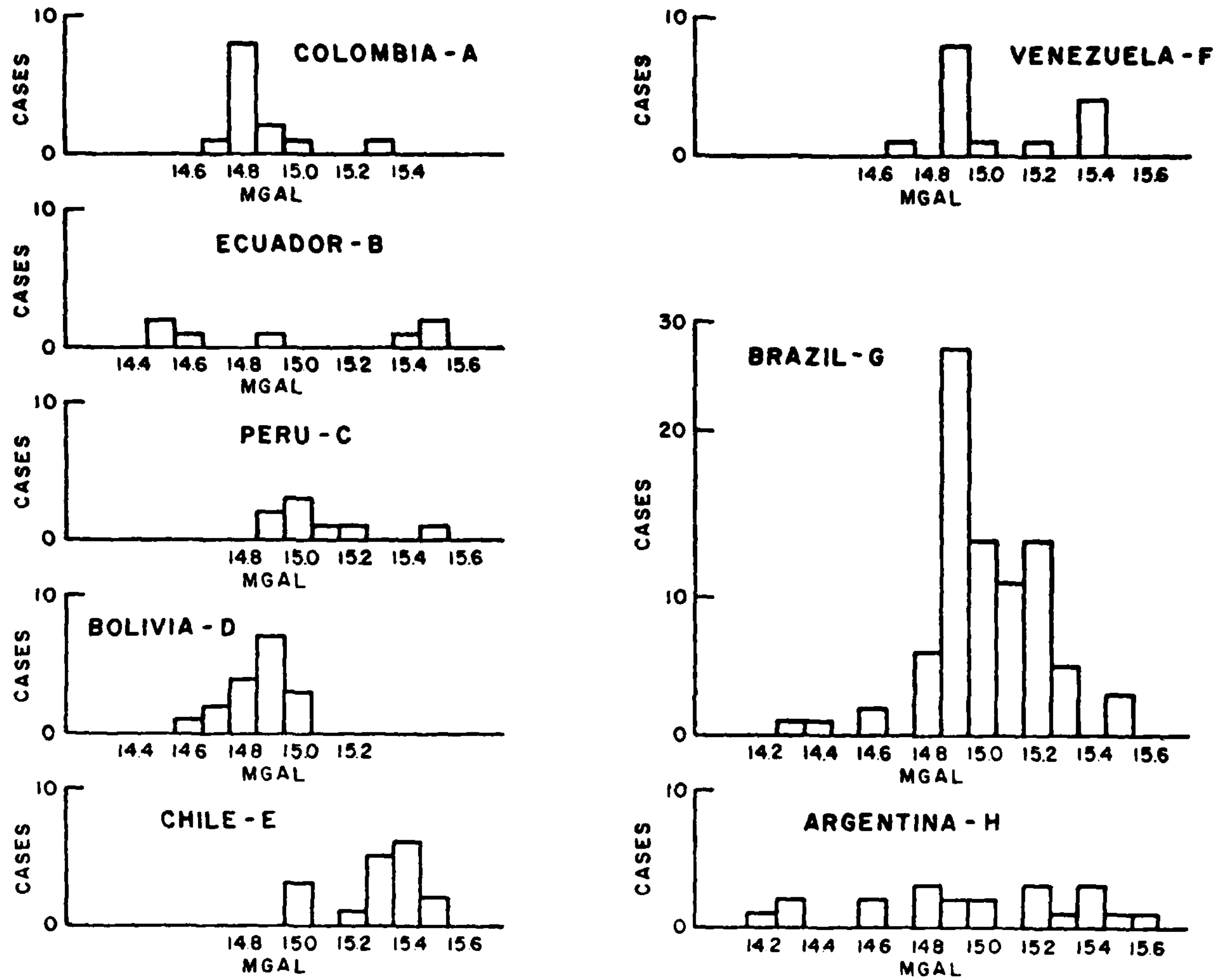



Fig. 13. Distribution plots of differences in Woollard and Rose (1963) values and IGSN 71 values in South America. A - Colombia. B - Ecuador. C - Peru. D - Bolivia. E - Chile. F - Venezuela. G - Brazil. H - Argentina.

differences in values for all sites in Colombia. The predominant value is 14.8 mgal and 11 of the 13 values would show agreement to ±0.1 mgal with this value. In Ecuador (Figure 13-B) the spread in values is large (14.5 to 15.5 mgal); no central tendency in values is indicated, and the average value is 15.0 mgal. In Peru (Figure 13-C) the small sample of data indicate a predominant value of 15.0 mgal; 6 of the 8 values do not depart by more than 0.1 mgal from this value. In Bolivia (Figure 13-D), the distribution, although somewhat skewed, indicates a predominant value of 14.9 mgal, and 14 of the 17 values do not depart by more than 0.1 mgal from this value. In Chile (Figure 13-E), which involves a large change in latitude, but where most of the sites are at relatively low elevations, the bimodal distribution with peaks of 15.0 mgal and about 15.35 mgal is to be expected because of the difference in gravity standard brought out at the gravity standardization bases.

As no difference in gravity standard was suggested by the comparisons at the gravity standardization bases in eastern South America, any skewness or bimodal distribution of the differences in the Woollard and Rose and IGSN values in this area are presumably related to tares. This is the situation suggested in Figure 13-F for Venezuela where the dominant difference in values is 14.9 mgal with a secondary peak at 15.4 mgal. In Figure 13-G, which shows the data for Brazil and includes a few sites in the Guianas for which there are comparative data, the distribution pattern is similarly bimodal. The predominant difference in values occurs at 14.9 mgal and at 15.2 mgal. Figure 13-H, which shows the data for Argentina plus single values for Paraguay and Uraguay, indicates no pronounced central tendency for the difference in values. The spread in values is abnormally large and the average value is about 15.0 mgal.

If the above differences in Woollard and Rose (1963) and IGSN 71 values are plotted as a function of absolute gravity, it is found that the indication of a difference in gravity standard from that of the IGSN values at the gravity standardization bases in the Andean region pertains to all of the Woollard and Rose values in South America. Figure 14-A is the plot of the differences in values as a function of absolute gravity at all sites in western South America coded to define the country to which the values pertain. Most of the values define a single alignment of values having the same mathematical expression as was defined at the gravity standardization bases; namely,

$$X = 14.7 + 0.2 \text{ (Woollard Rose value} - 977.0 \text{ gal)}.$$

A second parallel sector as a consequence of a tare of +0.55 mgal which involves 3 sites in Ecuador and 1 site each in Colombia and Peru -- all lie on the eastern (jungle) side of the Andes. That this same difference in gravity standard applies to values in eastern South America is brought out in Figure 14-B, which shows the differences in values grouped as before for Venezuela, Brazil and Argentina. Alignment (1), which involves most of the values for Venezuela and Brazil conform to that defined for the principal alignment of values in the Andean region. Alignment (2)

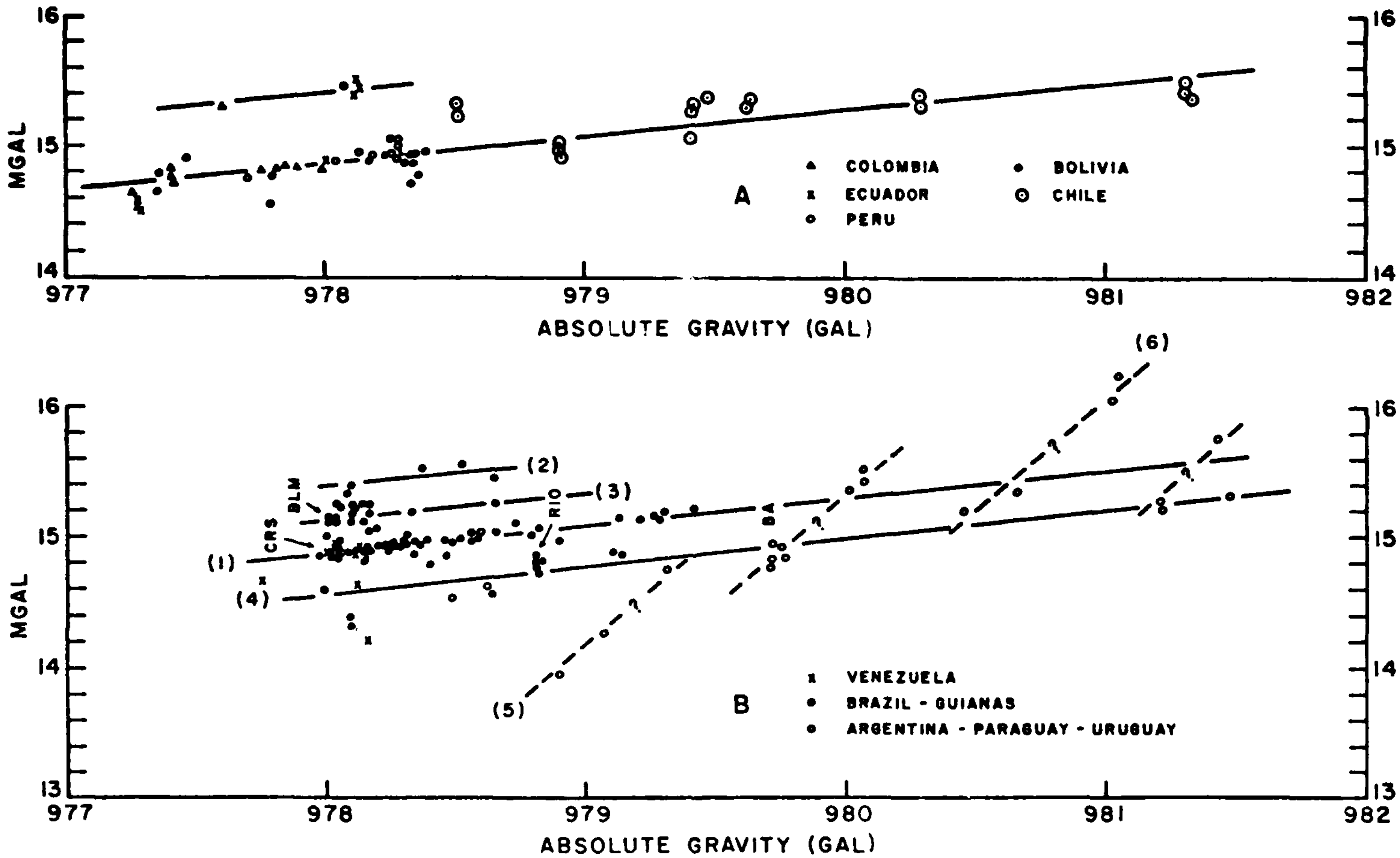



Fig. 14. Relation of differences in Woollard and Rose (1963) and IGSN 71 values to absolute gravity in South America. A - Colombia, Ecuador, Peru, Bolivia, and Chile. B - Venezuela, Brazil, the Guianas, Argentina, Uruguay, and Paraguay; CRS - Caracas; BLM - Belem; RIO - Rio de Janeiro; BA - Buencs Aires.

conforms to that for the secondary alignment of values in the Andean region and involves sites in the jungle area of Brazil. Alignment (3), which includes the Belem gravity standardization base, indicates that a tare occurred between Caracas, Venezuela and Belem, Brazil. The displacement of values from alignment (3) to alignment (4) indicates a negative tare between Belem and Rio de Janeiro. The apparent high angle parallel alignments of values in the data for Argentina are probably fortuitous, for although the relations are suggestive of those noted in Alaska and Mexico, the slopes are in opposite sign. It is more likely that the four values that depart significantly from alignments (1) and (4) are related to tares. The difference of 0.02 mgal per 1000 mgal in gravity standard indicated as characteristic of the Woollard and Rose values in South America, however, appears to be real, and is believed to be related to an undetected change in instrument calibration.

## COMPARISON OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES IN EUROPE AND AFRICA

The distribution plot for the differences in the Woollard and Rose (1963) and IGSN 71 values in Europe is shown in Figure 15-A. A bimodal distribution is indicated with predominant differences in values at 14.7 mgal and 14.9 mgal. However, 90% of the 68 values fall within bounds of ±0.2 mgal for a mean average of 14.7 mgal.

In Africa (Figure 15-B) the distribution in values is similarly bimodal, with peaks at 14.2 mgal and 14.7 mgal. This

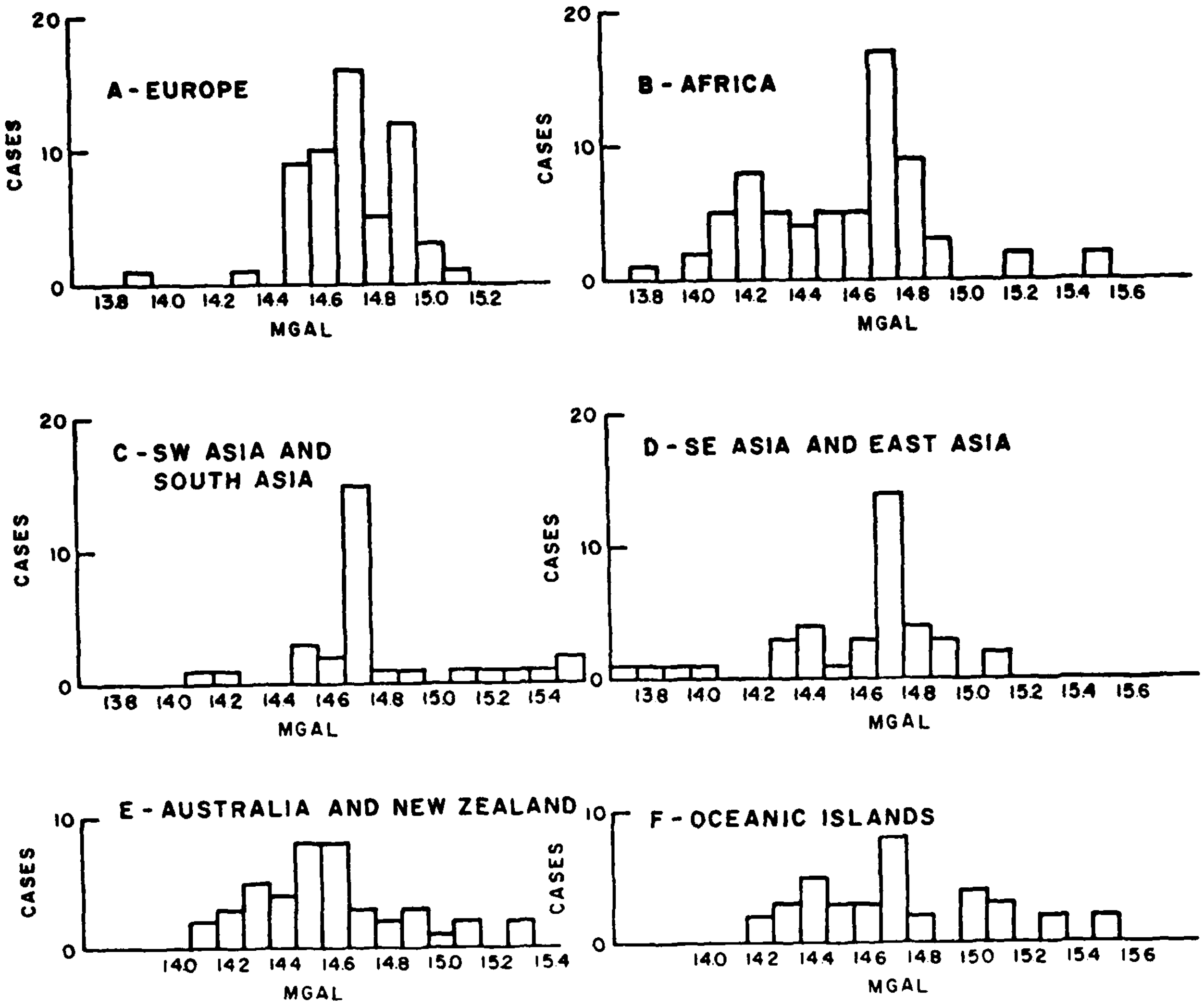



Fig. 15. Distribution plots of differences in Woollard and Rose (1963) values and IGSN 71 values in eastern hemisphere. A - Europe. B - Africa. C - Southwest and Southern Asia. D - Southeast and East Asia. E - Australia and New Zealand. F - Oceanic Islands.

distribution indicates a significant tare of 0.5 mgal that affects about 40% of the values.

The reality of the tares suggested by the bimodal nature of the distribution plots is brought out when the differences in values are plotted as a function of absolute gravity. Figure 16-A is the plot for the values in Europe, and two distinct alignments of values separated by 0.35 mgal are suggested. These alignments, if real, define a difference in gravity standard from that defined by the IGSN 71 values, and indicate a slope much the same as that noted in South America -- namely, +0.2 mgal per 1000 mgal increase in gravity. This, however, could be fortuitous as two similar parallel alignments of values having zero slope and differences of 14.9 and 14.6 mgal would satisfy the data equally well. If this pattern is assumed correct, 90% of all the values would lie within ±0.15 mgal of one or the other alignments.

The plot of the differences of the Woollard and Rose and IGSN 71 values as a function of absolute gravity in Africa (Figure 16-B), indicates no discernible difference in gravity standard from that of the IGSN 71 values. The pattern of tares brought out when the standardization bases were considered, however, is evident in that there are two alignments of values separated by 0.5 mgal. Alignments (1), which defines a mean datum difference of 14.7 mgal includes all the East African sites as well as those in North Africa except for sites in Ethiopia. Alignment (2), which is affected by the tare of -0.5 mgal, applies to all values between Nairobi and Johannesburg, and the

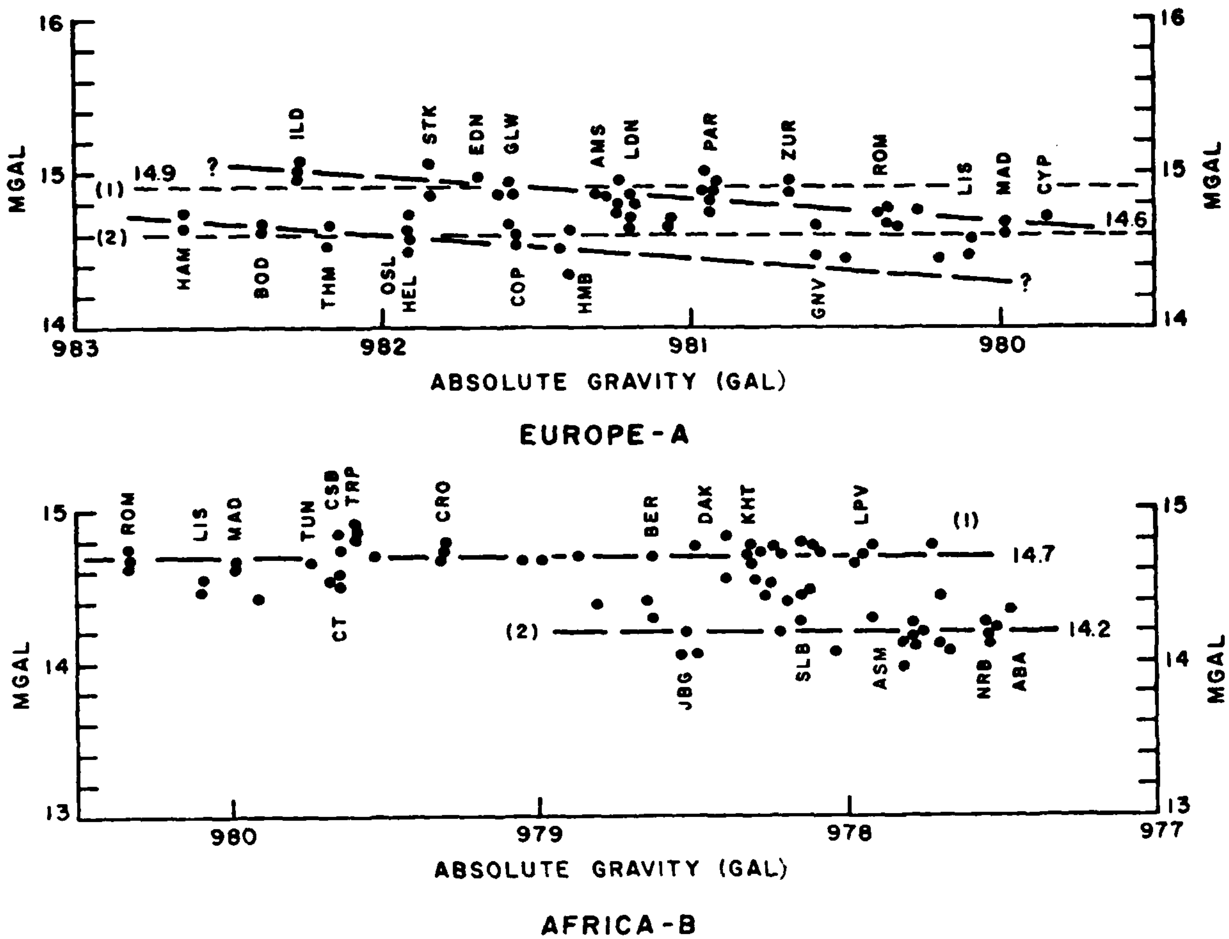



Fig. 16. Relation of differences in Woollard and Rcse (1963) and IGSN 71 values to absolute gravity in Europe and Africa.

A - Europe; Alignment (1) - ILD - Iceland; STK - Stockholm; EDN - Edinburgh; GLW - Glasgow; Ams - Amsterdam; LDN - London; PAR - Paris; ZUR - Zurich. Alignment (2) - HAM - Hammerfest; BOD - Bodo; THM - Trondheim; OSL - Oslo; HEL - Helsinki; COP - Copenhagen; HMB - Hamburg; GNV - Geneva; ROM - Rome; LIS - Lisbon; MAD - Madrid; CYP - Cyprus. B - Africa: Alignment (1) - ROM, LIS, MAD as in A. TUN - Tunis; CT - Capetown; CSB - Casablanca; TRP - Tripoli; CRO - Cairo; BER - Beira; DAK - Dakar; KHT - Khartoum; LPV - Leopoldville. Alignment (2) - JBG - Johannesburg; SLB - Salisbury; ASM - Asmara; NRB - Nairobi; ABA - Addis Ababa.

sites in Ethiopia.

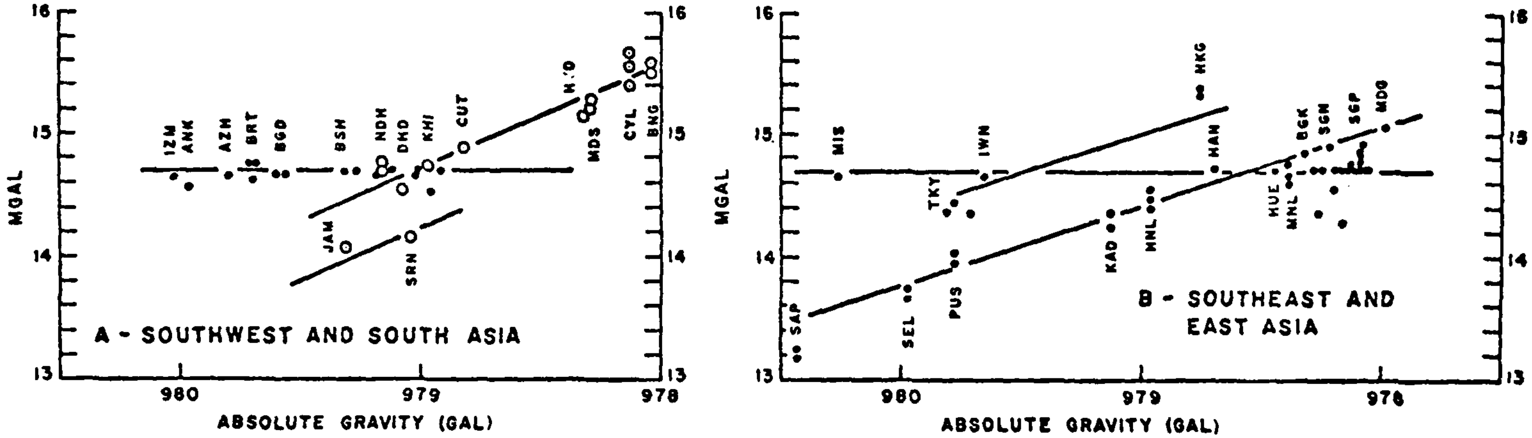
## COMPARISONS OF WOOLLARD AND ROSE (1963) AND IGSN 71 VALUES IN THE PACIFIC SECTOR AND OTHER AREAS

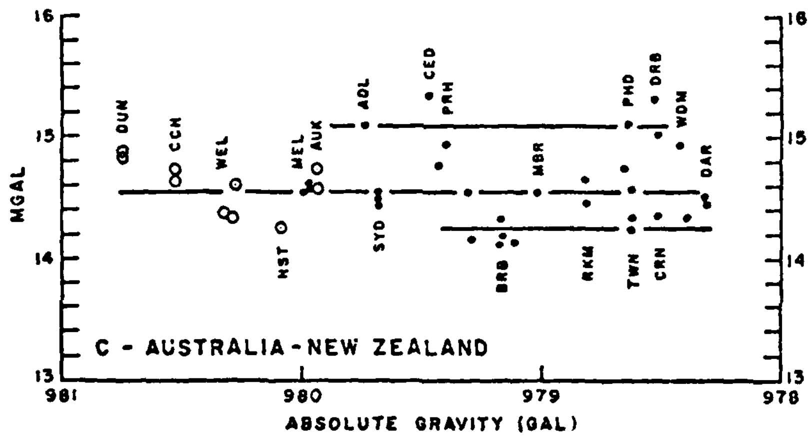
For comparing the Woollard and Rose values with IGSN 71 values in the Pacific and other areas, the data are subdivided by areas in separate series of measurements. These are: (1) Southeast and Southern Asia; (2) Southeast and East Asia; (3) Australia and New Zealand, and (4) oceanic islands in the Pacific, Indian and Atlantic Oceans.

### Southwest-South Asia Sector:

In Figure 15-C, the distribution plot of the differences in the Woollard and Rose values and the IGSN 71 values in Southwest and southern Asia is shown; the dominant value characterizing 48% of the 48 sites is 14.7 mgal. A similar value applies to sites in Southeast and East Asia and is brought out in Figure 15-D. Of the 34 sites involved 42% indicate a difference of 14.6 mgal. However, the wide spread in values in both areas suggests either that some of the observations were poor or else that there were some differences in some of the sites.

When the differences in the Woollard and Rose and IGSN 71 values in the above two sectors are plotted as a function of absolute gravity, the data for Southwest and southern Asia (Figure 17-A) indicate that whereas no difference in gravity standard is indicated in Turkey, the Persian Gulf region and Pakistan, there is a problem with the data for India. Either there is a marked difference in gravity standard for the values in India and




Legend

A - Southeast and southern Asia: IZM - Izmir; ANK - Ankara; AZH - Ain Zalah; BRT - Beirut; BGD - Baghbad; BSH - Basrah; NDH - New Delhi; DHD - Dehra Dun; KHI - Karachi; CUT - Calcutta; HYD - Hyderabad; CYL - Ceylon; BNG - Bangladore; JAM - Jammu; SRN - Srinager. B - Southeast and East Asia: MIS - Misawa; TKY - Tokyo; IWN - Iwakuni; HKG - Hong Kong; SAP - Sapporo; SEL - Seoul; PUS - Pusan; KAD - Kadena; HNL - Honolulu; HAN - Hanoi; MNL - Manila; BGK - Bangkok; SGN - Saigon; SGP - Singapore; MDG - Madang. C - Australia-New Zealand: Australian sites: ADL - Adelaide; CED - Ceduna; PRH - Perth; PHD - Port Hedland; DRB - Derby; WDM Wyndham; MEL - Melbourne; SYD - Sydney; MBR - Maryborough; DAR - Darwin; BRB - Brisbane; RKM - Rockhampton; TWN - Townsville; CRN - Cairns. New Zealand sites: DUN - Dunedin; CCH - Christchurch; WEL - Wellington; HST - Hastings; AUK - Auckland.

Fig. 17. Differences in Woollard and Rose (1963) values and IGSN 71 values in Asian and Australian-New Zealand sectors as a function of absolute gravity.

Ceylon as well as a tare, or there are two tares in opposite sign. The latter interpretation is regarded as being correct as nearly all of the values represented in Figure 17-A were determined as part of the same global series of observations using two Worden gravimeters. This interpretation is reinforced by the dominant difference value of 14.7 mgal brought out in the distribution plot of differences (Figure 15-C). It is much more likely, therefore, that the southern Indian observations are offset from those in central India by a tare that was not properly handled in reducing the data, as is clearly the case for the two observations (Jammu and Srinagar) in northern India.

Southeast-East Asia Sector:

The distribution plot for the differences in Woollard and Rose and IGSN 71 values in Southeast and East Asia (Figure 15-D) is very similar to that for Southwest and South Asia in that although there is a wide spread in values, one value is dominant (14.7 mgal). When the differences in values are plotted as a function of absolute gravity (Figure 17-B) relations are similar to those depicted in Figure 17-A for Southwest Asia and southern Asia. The data can be interpreted as defining a difference in gravity standard plus tares, or as defining no difference in gravity standard plus tares. As in southwest and southern Asia, the latter interpretation is regarded as being the correct one.

Australia - New Zealand Sector:

The distribution plot of the differences in the Woollard and Rose values and IGSN 71 values in Australia and New Zealand

(Figure 15-E) indicates what appears to be a trimodal distribution of values. The dominant value is about 14.55 mgal and the secondary peaks occur at 14.3 mgal and 14.9 mgal. When these values are plotted as a function of absolute gravity (Figure 17-C), it is seen that although no difference in gravity standard from that of the IGSN values is suggested, there are three parallel alignments of values separated by apparent tares of about -0.3 mgal and +0.6 mgal relative to the principal alignment.

Oceanic Islands Sector:

The distribution plot of the differences in the Woollard and Rose values and IGSN 71 values on oceanic islands (Figure 15-F) suggests three groupings of values corresponding to differences of 14.4 mgal, 14.7 mgal and 15.0 mgal. In considering these differences in values as a function of absolute gravity, the data were segregated into groups along with the land base values to which each set of island observations were tied in order to better define any difference in gravity standard from that of the IGSN 71 values. In Figure 18-A, the data are shown for the Atlantic Ocean sector with Glasgow, Scotland; Goose Bay, Labrador; Caribou, Maine; Washington, D.C. and Charleston, South Carolina representing land base sites for the northern sector, and Panama, Caracas, Venezuela and Recife and Rio de Janeiro, Brazil representing land base points for the southern sector. Alignment (1) indicates that the values for Guantanamo, Cuba; San Juan, Puerto Rico; and the Azores lie on the same line as that defined for Goose Bay, St. John, Newfoundland, Washington and Charleston and indicate a

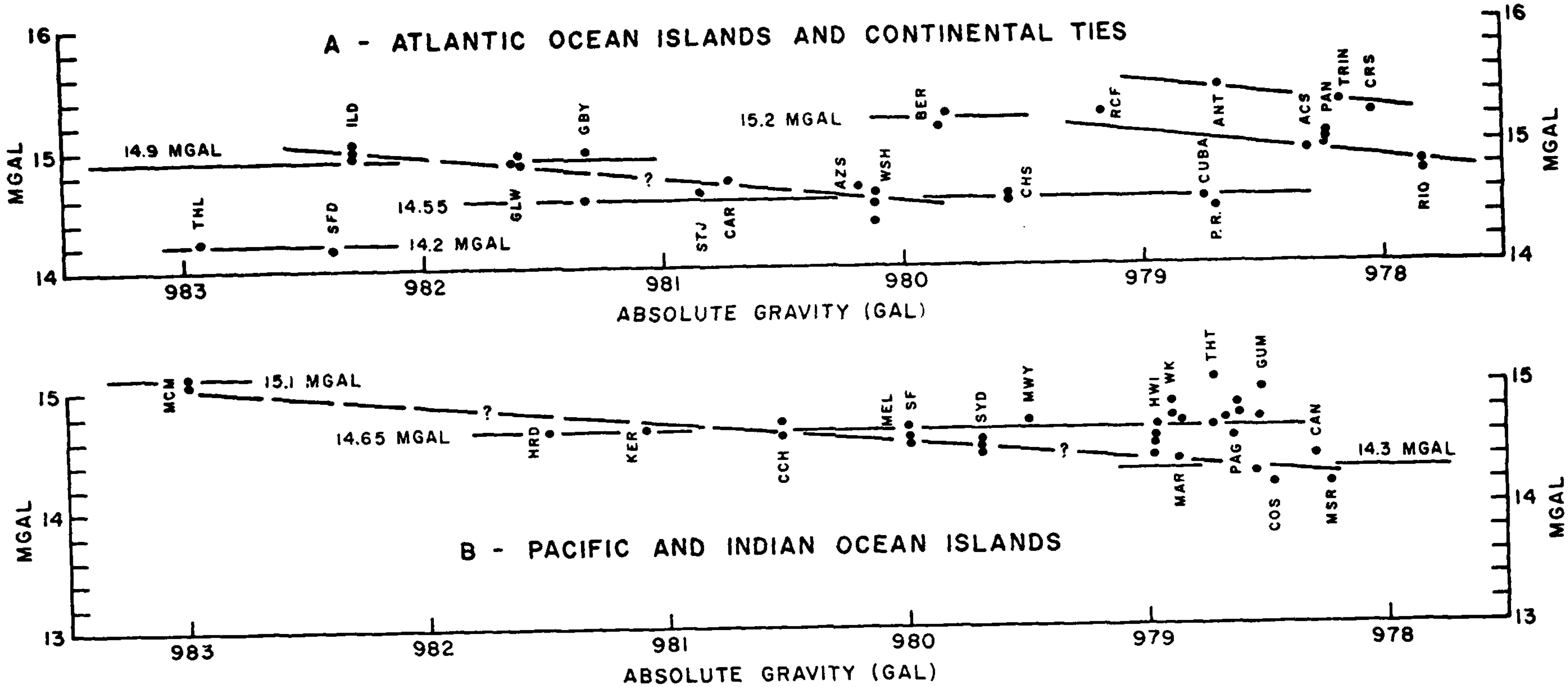



Fig. 18. Differences in Woollard and Rose (1963) values and IGSN 71 values on oceanic islands. A - Atlantic Ocean and continental tie bars: ILD - Iceland; GLW - Glasgow; GBY - Goose Bay; STJ - St. Johns; CAR - Caribou; AZS - *Azores*; WSH - *Washington*; BER - Bermuda; CHS - Charleston; RCF - Recife; ANT - Antiqua; ACS - Ascension; TRIN - Trinidad; CRS - Caracas; PAN - Panama; THL - Thule; SFD - Sondre Stromfjord. B - Pacific and Indian Ocean Islands: MCM - McMurdo; HRD - Heard; KER - Kerguelen; CCH - Christchurch; MEL - Melbourne; SF - San Francisco; SYD - Sydney; MWY - Midway; HWI - Hawaii; WK - Wake; MAR - Mauritius; THT - Tahiti; PAG - Pago Pago; GUM - Guam; COC - Cocos; CAN - Canton; MSR - Madagascar.

datum difference of 14.55 mgal with no difference in gravity standard from that of the IGSN 71 values. The values for Iceland (Keflavik and Reyjavik), however, which were connected from Goose Bay en route to Glasgow, Scotland, similarly indicate no difference in gravity standard from that of the IGSN 71 values, but a datum difference of 14.95 mgal. Although a slope could be fitted to this portion of the data from Washington this is regarded as fortuitous. This slope, however, is believed to apply to the data for Ascension Island in the South Atlantic area and its connections to Rio de Janeiro as well as to the data for Trinidad, Antigua and Caracas. The offsets in values for Bermuda (15.2 mgal) and for Thule and Sondre Stromfjord in Greenland (14.2 mgal) are believed to result from tares.

In the Pacific area if the three values for the Indian Ocean (Mauritius, Madagascar and Cocos Island) are disregarded along with the value for McMurdo, Antarctica, there is no evidence for any departure in gravity standard from that of the IGSN 71 values, and the datum offset indicated is 14.56 mgal. The sites in the Indian Ocean appear to have a datum difference of about 14.3 mgal and the value at McMurdo, Antarctica, indicates a difference in values of 15.1 mgal. That this last is a consequence of a tare rather than any difference in gravity standard is indicated by the data for Heard and Kerquelen Islands, which were observed on the same trip based out of Melbourne, Australia. The apparent alignment of values indicating a difference in gravity standard between McMurdo and Madagascar is therefore purely fortuitous.

## SUMMARY STATEMENT

In summary it would appear that the discrepancies in the Woollard and Rose (1963) values relative to the IGSN 71 values fall into three categories. The first, and by far the most extensive group of values, which characterizes all of North America (except Alaska and Mexico), Africa, Australia, New Zealand, Southwest and Southeast Asia and most of the Pacific and North Atlantic sectors, involves no difference in gravity standard from that incorporated in the IGSN 71 values, although there are regional differences in the datum offset values because of tares. The second group, which is associated with all measurements in South America and the South Atlantic sector, are characterized by a gravity standard that differs by +0.2 mgal per 1000 mgal increase in gravity from that incorporated in the IGSN 71 values. As with the first group, there are datum offsets due to tares between different segments of the data. The third group, which applies to the data for Alaska and Mexico, are characterized by a much more pronounced difference in gravity standard, of the order of 1.5 mgal per 1000 mgal change, as well as tares.

Despite the above diversity in the patterns of agreement between the Woollard and Rose (1963) values and the IGSN 71 values, the mean differences in values do not vary greatly, and as the degree of deviation on a worldwide basis is a measure of overall reliability, a distribution plot is shown in Figure 19 of the differences at all sites (787) at which comparisons could be made. As seen from Figure 19, a near-Gaussian distribution is indicated

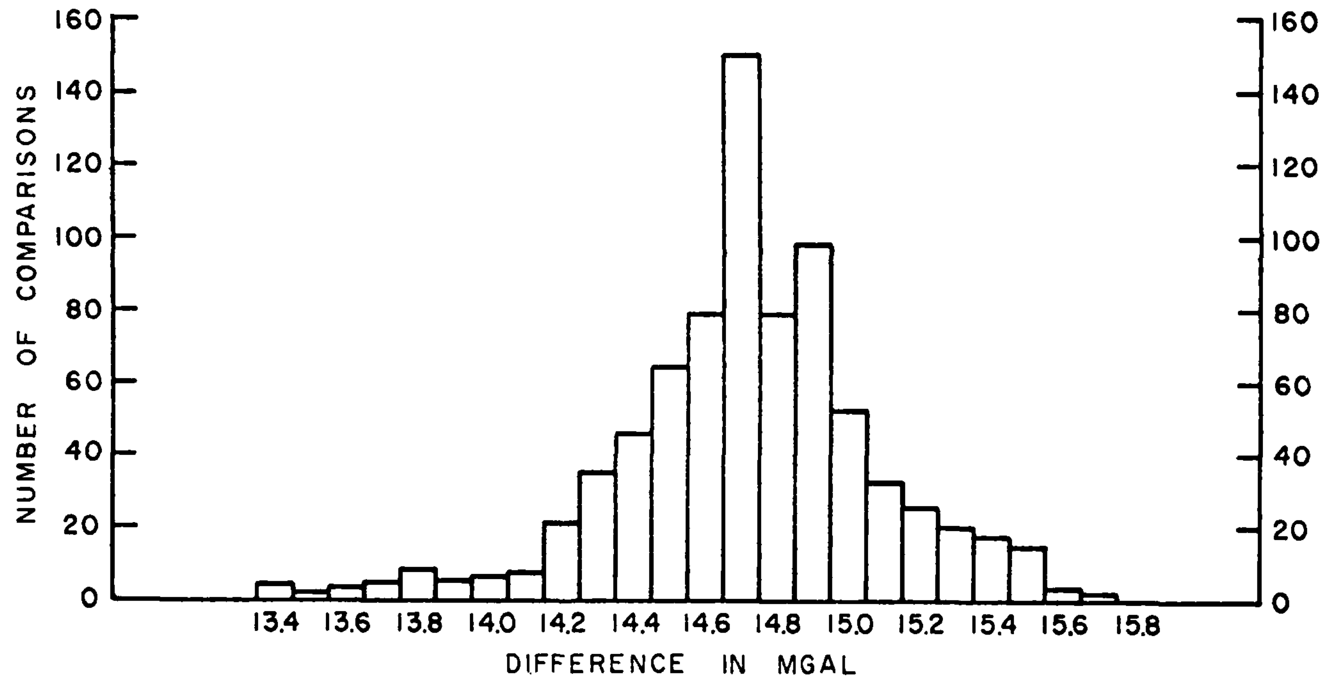



Fig. 19. Distribution plot of differences in Woollard and Rose and IGSN 71 values at all sites worldwide.

and the dominant value of difference (14.7 mgal) corresponds to that for the Madison, Wisconsin base value used by Woollard and Rose. Agreement to 0.1 mgal or better with this value is indicated at 196 sites (25% of the value). Agreement to 0.2 mgal or better is indicated at 474 sites (60% of the values), and agreement to 0.3 mgal or better is indicated at 576 (73% of the values). The standard deviation from the mean value of 14.7 mgal is 0.25 mgal. As this is without any allowance for any uncertainties in the IGSN 71 values or for the differences in the IGSN 71 values of Morelli et al (1974) and DMAAC, the overall degree of reliability conceivably could be somewhat better than indicated by the standard deviation. However, as brought out in the area-by-area comparisons, the quality of the Woollard and Rose (1963) values varies with area, and if these values are to be used to, in effect, extend the IGSN 71 network of base values, or to convert gravity surveys based on Woollard and Rose values to IGSN 71 equivalence, it has to be on the basis of these areal comparisons and individual site value differences. To facilitate such conversion of the Woollard and Rose values, tables of the differences in these values relative to IGSN 71 values for all individual sites for which there are comparative data have been prepared and filed with the SEG office. In the case of Woollard and Rose sites for which there are not comparative IGSN 71 values, the graphical areal comparisons included in this paper should permit IGSN 71 values to be approximated with a reasonable degree of reliability. In general, such approximations should have a reliability of about ±0.25 mgal or better.

# Appendix I

Tables of Differences in Gravity (Gravimeter) Values
Given in SEG Special Publication International Gravity Measurements
(Woollard and Rose, 1963) and IGSN 71 Gravity Values
As Determined by Morelli et al. (1974) and
By the U. S. Defense Mapping Agency Aerospace Center (unpublished)

## Preface

The values given in the following tables are only for sites that are believed to be the same and as described in SEG special publication International Gravity Measurements . Values that appear to be for the same site, but where the difference in values appears to be anomalous because of a site difference are indicated by a question mark. No values are included for sites that clearly are not the same. Otherwise, there was no editing of the 787 comparative values listed.

The tables are divided into two groups because of differences in coverage and slight differences in the IGSN 71 values as determined by Morelli et al. (1974) and the U.S. Defense Mapping Agency Aerospace Center (DMAAC). The differences in values are a consequence of differences in gravity standard of the order of 0.025 mgal per 1000 mgal that are not consistent in sign in going from one continental area to another. There are also datum offsets of the order of 0.02 to 0.04 mgal between continental areas. For these reasons, comparisons at the gravity standardization (pendulum) bases and their excenters are considered separately ( Appendix I) and the IGSN 71 values used are those of Morelli et al. (1974) which give more complete coverage for these sites than do the DMAAC values. However, the more restricted number of DMAAC IGSN 71 values for these bases are also listed for comparative purposes.

Tables in Appendix II are for all Woollard and Rose bases for which there are comparative IGSN 71 values. The IGSN 71 values of Morelli et al. (1974) are used wherever possible, and the DMAAC values while for comparative purposes at some sites, are in general on' · listed where there are no IGSN 71 values by Morelli et al. (1974). In all cases the DMAAC values are marked with an asterisk. As the standard deviation between the IGSN 71 values as determined by Morelli et al. (1974) and DMAAC at the 239 sites where comparisons could be made is ±0.01 mgal with 88 percent of the values agreeing to ±0.02 or better, this mixing of IGSN 71 values from two sources is not a matter of major concern in establishing the differences between the Woollard and Rose (1963) values and the IGSN 71 values.

For a complete analysis of the patterns of difference in tne Woollard and Rose values and IGSN 71 values on an areal basis, see "The Global Standardization of Gravity"(text of this report). For an analysis of the reliability of the IGSN 71 values particularly as regards the Potsdam datum correction and absolute gravity standard incorporated in these values as determined by Morelli et al. (1974), see "The New Gravity System (Woollard and Godley, 1980).

Table I-A

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values at Pendulum sites and their Excenters in North America

A - Western and Mid-Continent Series

Code: GW - Woollard and Rose pendulum site number (Intl. Gravity Meas. SEG 1963)
Dom. and USCGS: pendulum sites of Dominion Obs. and US Coast and Geod. Survey
WA - Woollard and Rose airport site number (Intl. Gravity Meas. SEG 1963)
WH - Woollard and Rose harbor site number (Intl. Gravity Meas. SEG 1963)
'A', 'B', 'C' - Pendulum or absolute gravity site. Intl. Grav. Bur. Paris
'J', 'K', 'L' - Airport or other excenter site. Intl. Grav. Bur. Paris

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| ALASKA | | | | | | |
| | Point Barrow | | | | | |
| GW 105 | Arctic Rsch. Lab. | 982.6996 | "B" .68500 | +14.60 | | |
| GW 5 | " " " | 982.6998 | "A" .68518 | +14.62 | .68517 | +14.63 |
| WA 280 | Airport | 982.6998 | "K" .68521 | +14.59 | | |
| | Fairbanks | | | | | |
| GW 6 | U of A Geophys. Inst. | 982.2462 | "A" .23171 | +14.49 | .23170 | +14.50 |
| GW 27 | Fort Wainwright | 982.2444 | "B" .22991 | +14.49 | | |
| Absolute | Rm 1, Patty Bldg Univ. Alaska | 982.2495 | "C" .23500 | +14.50 | | |
| WA 279 | Int'l. Airport | 982.2464 | "K" .23197 | +14.43 | | |
| WA 347 | Ft Wainwright AP | 982.2439 | "J" .22937 | +14.53 | | |
| | Anchorage | | | | | |
| USCGS | Elmendorf AFB | 981.9400 | "A" .92519 | +14.81 | | |
| WA 474 | " " | 981.9382 | "J" .92356 | +14.64 | | |
| WA 323 | Int'l. Airport | 981.9204 | "K" .90586 | +14.54 | .90582 | +14.58 |

Table I-A (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| CANADA | | | | | | |
| | Watson Lake, Yukon Territory | | | | | |
| Dom. Obs. | Airport manager | 981.7150 | "A" .70039 | +14.61 | | |
| WA 476 | AP outside term. | 981.7143 | "K" .69998 | +14.32 | | |
| | Whitehorse, Yukon Territory | | | | | |
| GW 26 | Airport Pump House | 981.7486 | "B" .73425 | +14.35 | | |
| WA 188 | Airport | 981.7487 | "J" .73425 | +14.45 | | |
| | Fort Nelson, British Columbia | | | | | |
| Dom Obs | Hotel | 981.6828 | | | .66817 | +14.63 |
| WA 182 | Airport | 981.6929 | "J" .67839 | +14.51 | | |
| | Fort St. John, British Columbia | | | | | |
| GW 27 | AP Adm. Bldg. | 981.4059 | "A" .39121 | +14.69 | | |
| WA 478 | Airport outside term. | 981.4055 | "J" .39078 | +14.72 | .39079 | +14.71 |
| | Vancouver, British Columbia | | | | | |
| Dom Obs | " | 980.9352 | "A" .92068 | +14.52 | .92068 | +14.52 |
| WA 186 | Int'l. Airport | 980.9299 | "J" .91541 | +14.49 | | |
| | Grande Prairie, Alberta | | | | | |
| Dom Obs | Post Office | 981.3180 | "A" .30322 | +14.78 | .30320 | +14.80 |
| GW 10 | School | 981.3175 | "B" .30285 | +14.65 | | |
| WA 183 | Airport tower | 981.3158 | "J" .30099 | +14.81 | | |
| | Edmonton, Alberta | | | | | |
| Pend. | Univ. Alberta | 981.1677 | "A" .15309 | +14.61 | .15309 | +14.61 |
| GW 25 | " " | 981.1678 | "B" .15316 | +14.64 | | |

Table I-A (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| GW 5 | Univ. Alberta | 981.1672 | "C" .15279 | +14.41 | | |
| WA 181 | Mun. Airport | 981.1729 | "K" .15838 | +14.52 | | |
| WA 282 | RCAF NAMAO | 981.1803 | "M" .16584 | +14.46 | | |
| | Calgary, Alberta | | | | | |
| GW 32 | AP Generator Bldg | 980.8281 | "A" .81355 | +14.55 | | |
| WA 180 | Terminal | 980.8288 | "J" .81425 | +14.55 | | |
| Dom Obs | Public Library | 980.8286 | "C" .81406 | +14.54 | .81406 | +14.54 |
| | Lethbridge, Alberta | | | | | |
| GW 33 | Post Office | 980.7589 | "A" .74462 | +14.28 | .74461 | +14.29 |
| GW 12 | Mun. Bldg | 980.6083 | "C" .74418 | +14.12 | | |
| WA 184 | Airport | 980.7538 | "J" .73915 | +14.65 | | |
| | UNITED STATES | | | | | |
| | Seattle, Washington | | | | | |
| GW 104 | Univ. Wash. | 980.7388 | "A" .72434 | +14.46 | .72434 | +14.46 |
| WA 170 | Int'l. Airport | 980.7765 | "K" .76202 | +14.48 | | |
| | Cutbank, Mont. | | | | | |
| GW 34 | Airport | 980.6085 | "B" .59383 | +14.67 | .59377 | +14.73 |
| | Great Falls, Montana | | | | | |
| GW 4 | Roosevelt Sch. | 980.5269 | "A" .51230 | +14.60 | .51229 | -14.59 |
| WA 482 | Mun. Airport | 980.5137 | "J" .49911 | +14.59 | | |
| WA 243 | Malmstrom AFB | 980.5291 | "K" .51452 | +14.58 | | |

Table I-A (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| | Billings Montana | | | | | |
| GW 25 | AP Hangar | 980.3710 | "A" .35637 | +14.63 | .35637 | +14.63 |
| WA 122 | Terminal | 980.3717 | "K" .35737 | +14.33 | | |
| | Sheridan, Wyoming | | | | | |
| GW 36 | AP Hangar | 980.2264 | "A" .21205 | +14.35 | | |
| WA 179 | Field | 980.2265 | "J" .21214 | +14.36 | .21214 | +14.36 |
| | Casper Wyoming | | | | | |
| GW 37 | AP Hangar | 979.9558 | | | .94133 | +14.47 |
| WA 177 | Field | 979.9562 | "J" .94159 | +14.61 | | |
| | Cheyenne, Wyoming | | | | | |
| GW 38 | AP Cafe | 979.7006 | "A" .68618 | +14.42 | .68619 | +14.41 |
| GW 17 | Hangar | 979.7008 | "B" .68630 | +14.50 | | |
| WA 178 | Field | 979.7008 | "J" .68623 | +14.57 | | |
| | Denver, Colorado | | | | | |
| Absolute | Univ. Denver | 979.6123 | "A" .59768 | +14.62 | .59770 | +14.60 |
| GW 39 | Chamberlain Obs. | 979.6117 | "B" .59710 | +14.60 | | |
| WA 89 | Stapleton Field | 979.6335 | "J" .61897 | +14.53 | | |
| | San Francisco, California | | | | | |
| GW 54 | Golden Gate Park | 979.9867 | "A" .97213 | +14.57 | | |
| WA 87 | Int'l. Airport | 979.9885 | "J" .97381 | +14.69 | | |

Table I-A (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| WA 86 | Int'l. Airport | 979.9883 | "K" .97375 | +14.55 | | |
| WA 202 | Travis AFB | 978.9898 | "P" .97538 | +14.42 | | |
| | Huron, South Dakota | | | | | |
| GW 24x | Hangar (USCG 1200) | 980.4530 | | | .43859 | -14.41 |
| | Madison, Wisconsin | | | | | |
| GW 31 | Univ. Wis. Sci. Hall | 980.3689 | "A" .35422 | +14.68 | .35422 | -14.68 |
| WA 76 | Truax Field | 980.3725 | "J" .35782 | +14.68 | | |
| | Chicago, Illinois | | | | | |
| GW 23 | Midway AP Hangar | 980.2873 | "A" .27262 | +14.68 | | |
| WA 101 | Midway Airport | 980.2864 | "J" .27179 | +14.61 | | |
| | Beloit, Kansas | | | | | |
| GW 52 | Phillips gas sta. | 979.9981 | | | .98359 | +14.51 |
| | Tulsa, Oklahoma | | | | | |
| GW 51 | Univ. Tulsa | 979.7661 | | | .75146 | +14.64 |
| | Amarillo, Texas | | | | | |
| GW 50 | Airport hangar | 979.4235 | "A" .40911 | +14.39 | | |
| WA 67 | AP Terminal | 979.4234 | "J" .40887 | +14.53 | .40887 | +14.53 |
| | Houston, Texas | | | | | |
| GW 18 | Rice Univ. | 979.2983 | "A" .28372 | +14.58 | .23772 | +14.58 |
| WA 159 | Old Int'l. Airport | 979.2932 | "J" .27866 | +14.64 | | |

Table I-A (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| | San Antonio, Texas | | | | | |
| GW 40 | Airport storeroom | 979.1975 | "A" .18273 | +14.77 | | |
| WA 162 | Airport field | 979.1976 | "J" .18286 | +14.74 | | |
| WA 161 | Airport Terminal | 979.1973 | "L" .18257 | +14.73 | | |

Table I-B

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values at Pendulum sites and their Excenters in North America

B - East Coast Series

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| CANADA | | | | | | |
| | <u>Ottawa, Ontario</u> | | | | | |
| GWA 53A | Dominion Obs. | 980.6208 | "A" .60614 | +14.66 | | |
| GW 53 | Geophys Lab. | 980.6217 | "B" .60710 | +14.60 | | |
| WA 310 | Mun. Airport | 980.6187 | "L" .60414 | +14.56 | | |
| UNITED STATES | | | | | | |
| | <u>Woods Hole, Massachusetts</u> | | | | | |
| GW 77 | WH Ocean. Inst. | 980.3273 | | | | |
| GW 77A | " " BM | 980.3271 | | | .31249 | +14.81 |
| WA 472 | Hyannis Airport | 980.3400 | | | .32541 | +14.59 |
| | <u>Palisades, New York</u> | | | | | |
| GW 1 | Lamont-Doherty | 980.2596 | | | | |
| WA 133 | Kennedy Airport | 980.2261 | "K" .21135 | +14.75 | .21134 | +14.76 |
| WA 132 | LaGuardia Airport | 980.2825 | "S" .26777 | +14.73 | | |
| | <u>Princeton, New Jersey</u> | | | | | |
| GW 78 | Univ. Guyot Hall | 980.1783 | "A" .16373 | +14.5? | | |
| GW 78A | Rm 14 Guyot | 980.1776 | "B" .16306 | +14.54 | | |

Table I-B (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| Absolute | Palmer Lab. | 980.1755 | "C" .16098 | +14.52 | | |
| WA 42 | McGuire AFB | 980.2128 | "J" .19836 | +14.44 | .19835 | +14.45 |
| | Washington, D. C. | | | | | |
| USCGS | Commerce Pier | 980.1188 | "A" .10429 | +14.51 | .10430 | +14.50 |
| GW 2 | Dept. Terr. Mag. CIW | 980.1006 | "D" .08605 | +14.55 | | |
| Absolute | Old Bu. Stds. | 980.0995 | "E" .08486 | +14.64 | | |
| WA 493 | National Airport | 980.1089 | "K" .09440 | +14.50 | | |
| Absolute | Bu. Stds. Gaithersburg Rm. 129, Bldg 202 | | "V" .10132 | | | |
| | Charleston, South Carolina | | | | | |
| GW 90 | Citadel Univ | 979.5509 | "A" .53635 | +14.55 | .53635 | +14.55 |
| WA 494 | Mun. Airport | 979.5667 | "J" .55216 | +14.54 | | |
| WA 148 | Mun. Airport BM | 979.5668 | "K" .55227 | +14.53 | | |
| WA 147 | MATS Term. | 979.5675 | "L" .55298 | +14.52 | | |
| | Miami, Florida | | | | | |
| GW 115 | U.M. Marine Biol. Lab. | 979.0356 | "A" .02095 | +14.65 | .02095 | +14.65 |
| WA 278 | Int'l. Airport | 979.0528 | "J" .03829 | +14.51 | | |
| WA 11 | Old EAL Term. | 979.0543 | "L" .03957 | +14.73 | | |
| | Key West, Florida | | | | | |
| GW 116 | US Naval Sta. | 978.9692 | "A" .95446 | +14.54 | | |
| WH 39 | " " gate | 978.9686 | "J" .95407 | +14.53 | | |

Table I-B (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| C - MEXICO - CENTRAL AMERICA Series | | | | | | |
| | Monterey, Nuevo Leon | | | | | |
| GW 21 | Inst. Technology | 978.8055 | "A" .79069 | +14.81 | .97069 | +14.81 |
| WA 190 | Airport | 978.8617 | "J" .84705 | +14.65 | | |
| | Mexico City, D. F. | | | | | |
| GW 43 | Univ. Mexico | 977.9414 | "A" .92650 | +14.90 | | |
| GW 41 | Tacubaya | 977.9419 | "O" .92715 | +14.75 | | |
| WA 189 | Int'l. Airport | 977.9701 | "J" .95542 | +14.68 | .95543 | +14.67 |
| WA 489 | Int'l. Airport | 977.9705 | "L" .95599 | +14.51 | | |
| | Paso de Cortes | | | | | |
| GW 42 | TV station | 977.5711 | "A" .55636 | +14.74 | | |
| GW B | Cortes monument | 977.6536 | "C" .63832 | +15.28 | | |
| PANAMA | | | | | | |
| GW 92 | Balboa C.Z. | 978.2417 | "A" .22670 | +15.0 | | |
| 92C | YMCA | 978.2391 | "O" .22400 | +15.10 | | |
| WA 4014 | Tocumen AP | 978.2665 | "J" .25144 | +15.06 | .25144 | +15.06 |
| WA 4004 | Albrook AFB | 978.2427 | "S" .22772 | +14.98 | | |
| WH 1015 | Rodman Navy Base | 978.2376 | "R" .22254 | +15.06 | | |

Table II-A

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values at Pendulum Sites and their Excenters in South America

A - West Coast (Andean) Series

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| PANAMA | | | | | | |
| GW 92 | Balboa C.Z. | 978.2417 | "A" .22670 | +15.00 | | |
| WA 4014 | Tocumen AP | 978.2665 | "J" .25144 | +15.06 | .25144 | +15.06 |
| GW 92x | Balboa YMCA | 978.2391 | "O" .22400 | +15.10 | | |
| WA 4004 | Albrook AFB | 978.2427 | "S" .22772 | +14.98 | | |
| WH 1015 | Rodman Navy Base | 978.2376 | "R" .22254 | +15.06 | | |
| COLOMBIA | | | | | | |
| GW 106 | Bogota IGM | 977.4049 | "A" .39011 | +14.79 | .39012 | +14.78 |
| Absolute | Bogota Univ. Nac. | 977.4049 | "C" .39014 | +14.76 | | |
| WA 6112 | AP Mun. Techo | 977.4017 | "J" .38691 | +14.79 | | |
| WA 6145 | Int'l. AP Eldorado | 977.3954 | "K" .38059 | +14.81 | | |
| ECUADOR | | | | | | |
| GW 94 | Quito | 977.2777 | "A" .26319 | +14.51 | | |
| WA 6121 | Panagra AP | 977.2860 | "J" .27144 | +14.56 | | |
| WA 6139 | Mariscal Scure AP | 977.2849 | "K" .27038 | +14.52 | | |
| PERU | | | | | | |
| GW 93 | Lima | 978.2830 | "A" .26794 | +15.06 | .26794 | +15.06 |

Table II-A(cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| WA 6126 | Limatambo AP | 978.2791 | "J" .26408 | +15.02 | | |
| WA 6140 | Callao Int'l. AP | 978.3072 | "K" .29218 | +15.02 | | |
| BOLIVIA | | | | | | |
| GW 95 | La Paz | 977.4671 | "A" .45219 | +14.91 | .45221 | +14.89 |
| WA 6134 | Braniff AP Term. | 977.3528 | "K" .33800 | +14.80 | | |
| WA 6020 | Panagra Term. | 977.3487 | "L" .33402 | +14.68 | | |
| CHILE | | | | | | |
| GW 99 | Antofogasta | 978.9045 | "A" .88952 | +14.98 | .89950 | +15.0 |
| WA 6105 | Cerro Moreno AP | 978.8853 | "K" .87030 | +15.00 | | |
| WA 6135 | old Cerro Moreno AP | 978.8830 | "L" .86804 | +14.96 | | |
| GW 96 | Santiago | 979.4294 | "A" .41411 | +15.29 | .41407 | +15.33 |
| WA 6110 | Los Cerrillos AP | 979.4500 | "K" .43468 | +15.32 | | |
| WH 1020 | Valparaiso Pier 1 | 979.6362 | "K" .62087 | +15.33 | | |
| WH 1058 | Valparaiso Lt. Hs. | 979.6342 | "L" .61890 | +15.30 | .61887 | +15.33 |
| GW 97 | Punta Arenas | 981.3159 | "A" .30049 | +15.41 | .30052 | +15.38 |
| WA 6108 | Old Term. | 981.3122 | "K" .29670 | +15.50 | | |
| WA 6136 | AP Term. | 981.3130 | "L" .29761 | +15.39 | | |
| WH 1019 | Port Adm. Bldg. | 981.3363 | "N" .32081 | +15.49 | | |

Table II-B

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values at Pendulum sites and their Excenters in South America

B - East Coast (Atlantic) Series

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| VENEZUELA | | | | | | |
| GW 107 | Caracas | 978.0399 | "A" .02472 | +15.18 | .02474 | +15.16 |
| WA 6131 | Maiguetia AP | 978.2460 | "K" .23106 | +14.94 | | |
| WH 1071 | La Guayra Hrb. | 978.2522 | "L" .23724 | +14.96 | | |
| BRASIL | | | | | | |
| GW 108 | Belem | 978.0374 | "A" .02224 | +15.16 | .02223 | +15.17 |
| WA 6032 | Airport | 978.0342 | "K" .01897 | +15.23 | | |
| WH 1012 | Tide gage | 978.0397 | "O" .02459 | +15.11 | | |
| WH 1055 | Pier BM | 978.0399 | "N" .02463 | +15.27 | | |
| GW 109 | Rio de Janeiro | 978.8047 | "A" .78990 | +14.80 | .78990 | +14.80 |
| WA 6082 | Galeao AP | 978.7978 | "J" .78305 | +14.75 | | |
| WA 6081 | Santos Dumont AP | 978.8084 | "L" .79355 | +14.85 | | |
| WH 1060 | Pier Da Praca Nana | 978.8076 | "O" .79278 | +14.82 | | |
| ARGENTINA | | | | | | |
| GW 98A | Buenos Aires | 979.7048 | "A" .69003 | +14.77 | .69003 | +14.77 |
| Univ Base | Meter. Obs. | 979.7060 | "C" .69116 | +14.84 | | |
| Univ Base | La Plata Obs. | 979.7517 | "O" .73685 | +14.85 | | |
| WA 6002 | Ezeisa AP | 979.7317 | "K" .71675 | +14.95 | | |

Table II-B(cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| Mateo Pend. | Cordoba Astr. Obs | 979.3419 | | | | |
| WA 6004 | Cordoba AP | 979.3271 | "K" .31234 | +14.76 | .31232 | +14.78 |
| WA 6007 | Mar del Plata AP | 980.0181 | | | .00273 | +15.37 |
| Mateo Pend. | Hotel Soldini, La Plata | 980.0340 | | | | |
| WA 6010 | Aeronaval AP | 981.2066 | "K" .19138 | +15.22 | .19134 | +15.26 |
| Mateo Pend. | Rio Gallegos School | 981.2126 | | | | |
| Mateo Pend. | Ushuaia Penitentiary | 981.4807 | "A" .46539 | +15.31 | | |

Table III

Comparisons of Woollard and Rose Gravimeter Values and IGSN 71 Values at Pendulum sites and their Excenters in Europe

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| NORWAY | | | | | | |
| GW 118 | Hammerfest | 982.6324 | "A" .61762 | +14.78 | .61762 | +14.78 |
| WH 1045 | Indrefjord | 982.6301 | "J" .61548 | +14.62 | | |
| GW 117 | Bodo | 982.3873 | "A" .37265 | +14.65 | .37264 | +14.66 |
| WA 5037 | Airport tower | 982.3876 | "J" .37297 | +14.63 | | |
| GW Pend | Trondheim Phys. Inst. | 982.1614 | "A" .14674 | +14.66 | .14672 | +14.68 |
| WA 5040 | Vaernes AP | 982.1523 | "K" .13779 | +14.51 | | |
| GW 68 | Oslo (Geol. Mus.) | 981.9272 | "A" .91261 | +14.59 | .91261 | +14.59 |
| WA 5038 | Fornebu AP | 981.9307 | "J" .91620 | +14.50 | | |
| FINLAND | | | | | | |
| IGM Sta | Helsinki Univ. | 981.9152 | "A" .90059 | +14.61 | .90059 | +14.61 |
| WA 5019 | Sentula AP | 981.9248 | "S" .91009 | +14.71 | | |
| SWEDEN | | | | | | |
| Kartverk | Stockholm | 981.8465 | "A" .83143 | +15.07 | | |
| WA 5053 | Bromma AP | 981.8455 | "J" .83066 | +14.84 | | |

Table III (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|---|
| **DENMARK** | | | | | | | |
| GW 64 | Copenhagen | 981.5577 | "B" | .54319 | +14.51 | | |
| WA 5004 | Kastrup AP | 981.5573 | "J" | .54275 | +14.55 | | |
| WA 5059 | Kastrup AP | 981.5568 | "L" | .54226 | +14.54 | | |
| **WEST GERMANY** | | | | | | | |
| GW 63 | Bad Harzburg | 981.1803 | "A" | .16550 | +14.80 | | |
| GW 63A | Braunshweig Abs. | 981.2668 | "C" | .25184 | +14.96 | .25183 | +14.97 |
| Abs Pier | Potsdam | 981.2749 | "A" | .26019 | +14.71 | | |
| GW 62 | Frankfurt | 981.0610 | "A" | .04632 | +14.68 | | |
| WA 5028 | Airport | 981.0571 | "J" | .04243 | +14.67 | | |
| ENGLAND | | | | | | | |
| GW 67 | Teddington | 981.1966 | "A" | .18178 | +14.82 | .18177 | +14.83 |
| WA 5012 | London AP Term 1 | 981.2003 | "J" | .18558 | +14.72 | | |
| WA 5013 | old Term | 981.2017 | "M" | .18704 | +14.66 | | |
| Camb.Pend. | Cambridge Univ. | 981.2688 | | | | .25394 | +14.86 |
| SCOTLAND | | | | | | | |
| Camb.Pend. | Edinburgh R. Obs. | 981.5839 | "A" | .56897 | +14.93 | .56895 | +14.95 |
| WA 5047 | Prestwick AP | 981.5784 | "J" | .56351 | +14.89 | | |
| WA 5046 | Prestwick MATS | 981.5758 | "K" | .56113 | +14.67 | .56111 | +14.69 |

Table III (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| WA 5044 | Glasgow Renfew AP | 981.6018 | "N" .58692 | +14.98 | | |
| Camb-Pend. | Aberdeen, Marischal | 981.6998 | | | .68482 | +14.98 |
| IRELAND | | | | | | |
| Camb. Pend. | Dublin Dunsink Obs, | 981.3891 | | | .37478 | +14.32 |
| NETHERLANDS | | | | | | |
| Pend. Base | DeBilt. K.M.O. | 981.2693 | | | .25456 | +14.74 |
| WA 5036 | Amsterdam AP | 981.2882 | "J" .27340 | +14.80 | | |
| FRANCE | | | | | | |
| CW 114 | Paris (SEVRES) | 980.9409 | "A" .92597 | +14.93 | .92596 | +14.94 |
| Gm Base | Paris Obs. "A" | 980.9434 | "B" .92865 | +14.75 | | |
| Pend. Base | Paris Obs. pier | 980.9432 | "E" .92829 | +14.91 | | |
| WA 5058 | Orly AP Term. | 980.9160 | "N" .90101 | +14.99 | | |
| WA 5024 | Le Bourget AP | 980.9502 | "J" .93534 | +14.86 | | |
| SPAIN | | | | | | |
| Pend. Base | Madrid, Astro. Obs. | 979.9812 | "A" .96652 | +14.68 | .96652 | +14.68 |
| Gm Base | Madrid IGC | 979.9703 | "C" .95561 | +14.69 | | |
| WA 5049 | Barajas AP | 979.9988 | "J" .98414 | +14.64 | | |
| WA 5051 | Torrejon AFB | 980.0072 | "M" .99251 | +14.69 | | |

Table III (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|---|
| PORTUGAL | | | | | | | |
| GW 110 | Lisbon IGC | 980.0903 | "A" | .07573 | +14.57 | .07571 | +14.59 |
| WA 5041 | Lisbon AP | 980.0796 | "K" | .06512 | +14.48 | | |
| SWITZERLAND | | | | | | | |
| Pend. Base | Zurich Geod. Inst. | 980.6670 | "A" | .65213 | +14.87 | .65212 | +14.88 |
| WA 5055 | Kloten AP | 980.6871 | "J" | .67218 | +14.92 | | |
| ITALY | | | | | | | |
| GW 61 | Rome Univ. Physics | 980.3639 | "A" | .34923 | +14.67 | | |
| Natl Base | Univ. Fac. Ing. | 980.3619 | "B" | .34722 | +14.68 | | |
| | Roco de Papa Obs. | 980.1929 | "C" | .17843 | +14.47 | | |
| WA 5033 | Ciampino Est AP | 980.3489 | "J" | .33427 | +14.63 | | |
| WA 5034 | Ciampino Ovest AP | 980.3478 | "M" | .33319 | +14.61 | | |
| WA 5060 | Fiumicino Int'l AP | 980.3765 | "N" | .36176 | +14.74 | | |
| LEBANON | | | | | | | |
| LeJay Pend. | Beirut Fac. Med. | 979.6909 | "A" | .67625 | +14.65 | .67624 | +14.66 |
| WA 2050 | Khalde AP (a) | 979.6934 | "J" | .67864 | +14.76 | | |
| WA 2051 | Khalde AP (b) | 979.6922 | "K" | .67744 | +14.76 | | |

Table IV-A

Comparison of Woollard and Rose Gravimeter Values and IGSN 71 Values at Pendulum sites and their Excenters in Africa

A - Mid-continent Series

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| CYPRUS | | | | | | |
| Camb. Pend | Nicosia | 979.8492 | | | .83449 | +14.71 |
| LIBYA | | | | | | |
| GW 60 | Tripoli-Wheelus | 979.5876 | "A" .57272 | +14.88 | .57273 | +14.87 |
| WA 1021 | Idris AP | 979.5379 | "L" .52300 | +14.90 | | |
| EGYPT | | | | | | |
| GW 69 | Cairo Helwan Obs | 979.2915 | "B" .27676 | +14.74 | | |
| WA 1002 | Farouk Int'l AP | 979.3160 | "L" .30125 | +14.75 | | |
| ETHIOPIA | | | | | | |
| GW 76 | Asmara (Kagnew) | 977.8194 | "A" .80545 | +13.95 | .80545 | +13.95 |
| WA 1005 | Mun. AP | 977.8224 | "J" .80826 | +14.14 | | |
| SUDAN | | | | | | |
| GW 70 | Khartoum Univ | 978.3034 | "B" .28867 | +14.73 | | |
| GW 70A | Univ. pend. site | 978.3033 | "A" .28864 | +14.66 | | |
| WA 1045 | Airport Term. | 978.3034 | "L" .28865 | +14.75 | .28863 | +14.77 |

Table IV-A (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|---|
| KENYA | | | | | | | |
| GW 71 | Nairobi | 977.5403 | "A" | .52607 | +14.23 | .52607 | +14.23 |
| Camb P. | Bullard (1) | 977.5279 | "C" | .51375 | +14.15 | | |
| WA 1014 | Eastleigh AP | 977.5430 | "J" | .52877 | +14.23 | | |
| WA 1015 | West Civil AP | 977.5357 | "K" | .52151 | +14.19 | | |
| ZAMBIA | | | | | | | |
| GW 75 | Lusaka AP | 978.0536 | "A" | .03929 | +14.31 | | |
| RHODESIA | | | | | | | |
| Camb P. | Salisbury | 978.1481 | "A" | .13365 | +14.45 | .13363 | +14.47 |
| WA 1043 | Belvedere AP | 978.1484 | "J" | .13414 | +14.26 | | |
| SOUTH AFRICA | | | | | | | |
| GW 73 | Johannesburg BPI | 978.5495 | "A" | .53546 | +14.04 | .53547 | +14.03 |
| WA 106[illegible] | Jan Smuts AP | 978.5503 | "K" | .53610 | +14.20 | | |
| Camb P | Pretoria Mus. | 978.6296 | "A" | .61530 | +14.30 | | |
| GW 74 | Capetown, Mowbroy | 979.6473 | "A" | .63271 | +14.59 | .63271 | +14.59 |
| Camb P | Royal Obs. | 979.6535 | "B" | .63893 | +14.57 | | |
| WA 10[illegible]1 | Malon AP | 979.6462 | "J" | .63145 | +14.75 | | |
| WA 1056 | Wingfield AP | 979.6494 | "L" | .63484 | +14.56 | | |

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PROGRESS IN THE GLOBAL STANDARDIZATION OF GRAVITY: AN ANALYSIS --ETC(U)
DEC 80 G P WOOLLARD, V M GODLEY N00014-75-C-0209
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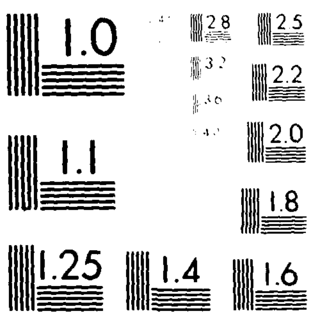


MICROCOPY RESOLUTION TEST CHART

Table IV-B

Comparison of Woollard and Rose Gravimeter Values and IGSN 71 Values at Pendulum sites and their Excenters in Africa

B - West Coast Series

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| SENEGAL | | | | | | |
| GW 111 | Dakar. Mbour | 978.3852 | "B" .37039 | +14.81 | | |
| WA 1010 | Yof AP | 978.4772 | "J" .46242 | +14.78 | | |
| GHANA | | | | | | |
| GW 112 | Accra Univ. | 978.1059 | "A" .09141 | +14.49 | | |
| WA 1012 | Airport | 978.1153 | "J" .10052 | +14.78 | | |
| ZAIRE (Congo) | | | | | | |
| GW 113 | Kinshasa (Leopoldville) | 977.9146 | "A" .89982 | +14.78 | .89984 | +14.76 |
| WA 1037 | Int'l. AP | 977.9518 | "J" .93713 | +14.67 | | |
| WA 1038 | Ndjili AP | 977.9429 | "M" .92820 | +14.70 | | |
| SOUTH WEST AFRICA | | | | | | |
| Camb P | Windhoek | 978.3205 | | | | |
| WA 1022 | AP Traffic Contr. | 978.3210 | | | .30629 | +14.71 |
| Camb P | Tsumeb | 978.2212 | | | | |
| WA 1070 | Airport | 978.2209 | | | .20619 | +14.71 |

Table V

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values at Pendulum sites and their Excenters

Pacific-Australian Series

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| HAWAII | | | | | | |
| GW 55 | Honolulu, Bishop Mus. | 978.9530 | "B" .93835 | +14.65 | .93836 | +14.64 |
| Pend | Univ, Inst. Geophys. | 978.9593 | "A" .94490 | +14.40 | | |
| WA 443 | Hickam AFB | 978.9337 | "J" .91914 | +14.56 | | |
| WA 444 | Old Int'l. AP | 978.9325 | "S" .91810 | +14.40 | | |
| | New Int'l. AP | 978.9335 | "Q" .91893 | +14.57 | | |
| | Inter Is. AP | 978.9330 | "R" .91843 | +14.57 | | |
| JAPAN | | | | | | |
| GW 103 | Sapporo, Hokkaido | 980.4406 | "B" .42735 | +13.25 | | |
| WA 2030 | Chitose AP | 980.4405 | "J" .42734 | +13.16 | | |
| GW 57 | Tokyo Univ. ERI | 979.8016 | "A" .78722 | +14.38 | | |
| WA 2037 | Hanenda AP | 979.7736 | "L" .75916 | +14.44 | | |
| Pend Base | Kyoto Univ. | 979.7216 | "A" .70727 | +14.33 | .70729 | +14.31 |
| GW 100 | Kadena, Okinawa | 979.1265 | "A" .11222 | +14.28 | | |
| WA 2057 | Kadena MATS | 979.1343 | "J" .11992 | +14.38 | | |
| PHILIPPINES | | | | | | |
| GW 58 | Manila, Clark AFB | 978.3969 | "A" .38230 | +14.60 | | |
| WA 2061 | Clark MATS | 978.3965 | "J" .38183 | +14.67 | | |
| WA 2062 | Manila Int'l. AP | 978.3767 | 'K' .36192 | +14.78 | | |

Table V (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| HONG KONG | | | | | | |
| GW 101 | US Consulate | 978.7677 | "A" .75231 | +15.39 | | |
| WA 2008 | Kai-Tak AP | 978.7730 | "J" .75766 | +15.34 | | |
| VIETNAM | | | | | | |
| Lejay Pend. | Saigon | 978.2285 | | | | |
| WA 2081 | Tan San Nhut AP | 978.2300 | "J" .21509 | +14.91 | .21509 | +14.91 |
| SINGAPORE | | | | | | |
| GW 102 | Univ. Malaya | 978.0815 | "A" .06668 | +14.82 | .06668 | +14.82 |
| Pend. Base | Raffles Mus. | 978.0809 | "B" .06604 | +14.86 | | |
| WA 2071 | Changi Crk. RAFB | 978.0801 | "E" .06521 | +14.89 | | |
| WA 2072 | Kallang AP | 978.0817 | "J" .06681 | +14.89 | | |
| WA 2073 | Paya Lebar AP | 978.0804 | "L" .06561 | +14.79 | | |
| AUSTRALIA NORTHERN TERRITORY | | | | | | |
| GW 88 | Darwin (BMR Bldg.) | 978.3140 | "A" .29955 | +14.45 | .29955 | +14.45 |
| WA 3058 | RAF Officers Club | 978.3164 | "B" .30192 | +14.48 | | |
| WA 3014 | Airport | 978.3154 | "J" .30093 | +14.47 | | |
| WA 3013 | Daly Waters BMRP | 978.3892 | | | .37487 | +14.33 |

Table V (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| QUEENSLAND | | | | | | |
| GW 87 | Cairns | 978.5006 | "A" .48624 | +14.36 | | |
| GW 86 | Townsville RAF | 978.6247 | "B" .61043 | +14.27 | | |
| WA 3043 | Airport | 978.6240 | "C" .60966 | +14.34 | .60969 | +14.31 |
| GW 85 | Brisbane Univ. | 979.1695 | "B" .15516 | +14.34 | | |
| GW 85A | Seismic vault | 979.1701 | "A" .15593 | +14.17 | | |
| WA 3004 | Eagle Farm AP | 979.1599 | "J" .14557 | +14.33 | | |
| WA 3067 | Archer AP | 979.1683 | "K" .15411 | +14.19 | | |
| BMR P | Rockhampton Jail | 978.8707 | "A" .85606 | +14.64 | .85606 | +14.64 |
| WA 3038 | Airport | 978.8738 | "J" .85935 | +14.45 | | |
| WA 3027 | Maryborough BMR Pend. | 979.0219 | "A" .00732 | +14.58 | | |
| NEW SOUTH WALES | | | | | | |
| GW 84 | Sydney (N.S.L.) | 979.6863 | "A" .67186 | +14.44 | .67185 | +14.45 |
| WA 3043 | Kingsford-Smith AP | 979.6993 | "J" .68480 | +14.50 | | |
| WA 3041 | Rose Bay AP | 979.6965 | "L" .68198 | +14.52 | | |
| VICTORIA | | | | | | |
| GW 38 | Melbourne BMR | 979.9797 | "A" .96518 | +14.52 | .96516 | +14.54 |
| WA 3028 | Essendon AP | 979.9628 | "J" .94821 | +14.59 | | |
| BMR Pend. | Kallista Forest Ranger Sta. | 979.9100 | "S" .89538 | +14.62 | | |

Table V (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|---|
| SOUTH AUSTRALIA | | | | | | | |
| BMR Pend. | Adelaide Univ. | 979.7243 | | | | .70920 | +15.10 |
| WESTERN AUSTRALIA | | | | | | | |
| BMR P | Perth Univ. | 979.3958 | "A" | .38086 | +14.94 | .38066 | +15.14 |
| WA 3035 | Airport | 979.4011 | "K" | .38632 | +14.78 | | |
| WA 3015 | Derby BMR Pend. | 978.5207 | | | | .50569 | +15 01 |
| WA 3036 | Port Hedland | 978.6466 | | | | .63150 | +15.1[illegible] |
| NEW ZEALAND NORTH ISLAND | | | | | | | |
| GW 81 | Wellington (L. Hutt) | 980.2934 | "C" | .27909 | +14.31 | | |
| Pend Base | Wellington DSIR | 980.2656 | "A" | .25100 | +14.60 | .25099 | +14.61 |
| WA 3058 | Rongotai AP | 980.3064 | "K" | .29201 | +14.39 | | |
| DSIR | Auckland WM Mus. | 979.9487 | "B" | .93411 | +14.59 | | |
| WA 3047 | Whenuapai AP | 979.9408 | "C" | .92604 | +14.76 | | |
| NEW ZEALAND SOUTH ISLAND | | | | | | | |
| GW 79 | Christchurch | 980.5089 | "A" | .49429 | +14.61 | .49429 | +14.61 |
| WA 3103 | Int'L Airport | 980.4962 | "L" | .48159 | +14.61 | | |
| WA 3049 | Harewood AP | 980.4962 | "K" | .48147 | +14.73 | | |
| GW 89 | Dunedin, Otago Univ. | 980.7424 | "A" | .72753 | +14.87 | .72751 | +14.89 |
| WA 3051 | Taieri Airport | 980.7366 | "C" | .72175 | +14.85 | | |

Table V (cont.)

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff (mgal) |
|---|---|---|---|---|---|---|
| ANTARCTICA | | | | | | |
| GW 82 | McMurdo | 982.9919 | "A" .97683 | +15.07 | .97683 | +15.07 |
| WA 9013 | Scott Base | 982.9883 | "L" .97318 | +15.12 | | |
| GW 119 | Mirny | 982.4052 | | | .39059 | +14.61 |
| GW 120 | Mawson | 982.4818 | | | .46719 | +14.61 |

Table VI

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values at Pendulum sites and their Excenters

India and Iceland

| | | (1) Woollard and Rose | (2) IGSN 71 | 1-2 Diff/ (mgal) | (3) IGSN 71 DMA AC | 1-3 Diff/ (mgal) |
|---|---|---|---|---|---|---|
| INDIA | | | | | | |
| GW 59 | New Delhi | 979.1363 | "A" .12155 | +14.75 | | |
| WA 2019 | Palam AP | 979.1341 | "J" .11938 | +14.72 | | |
| WA 2020 | Willingdon AP | 979.1379 | "K" .12316 | +14.74 | | |
| Natl.Gr. Base | Dehra Dun | 979.0636 | "A" .04909 | +14.51 | .04908 | +14.52 |
| SI Pend. | Bangaladore | 978.0294 | "A" .01389 | +15.51 | .01389 | +15.51 |
| WA 2011 | Bangaladore AP | 978.0387 | "J" .02314 | +15.56 | | |
| SI Pend. | Madras Metr. Cntr. | 978.2818 | "A" .26655 | +15.25 | .26655 | +15.25 |
| WA 2018 | St. Thomas Mt. AP | 978.2804 | "J" .26516 | +15.24 | | |
| CEYLON | | | | | | |
| SI Pend. | Colombo Metr. Obs. | 978.1328 | "B" .11724 | +15.56 | | |
| Mejnesz Pend. | French Consulate | 978.1403 | "C" .12454 | +15.76 | .12454 | +15.76 |
| WA 2004 | Ratmalana AP | 978.1323 | "J" .11690 | +15.40 | | |
| ICELAND | | | | | | |
| IGM Base | Reykjavik Univ. | 982.2800 | "A" .26496 | +15.04 | | |
| WH 1035 | Long Pier | 982.2813 | "J" .26634 | +14.96 | | |
| WA 7006 | Keflavik AP | 982.2744 | "K" .25943 | +14.97 | | |
| WA 7007 | Reykjavik AP | 982.2784 | "L" .26333 | +15.07 | | |

# Appendix II

## Tables of Differences in Woollard and Rose (1963) Gravimeter Values and IGSN Values on an Areal Basis

Sites with designations "A', 'B', 'C", "J", etc. are compared against the IGSN 71 values of Morelli et al. (1974). At all other sites the comparison is with the IGSN 71 values derived by the U.S. Defense Mapping Agency Aerospace Center (unpublished). Values followed by * are DMAC values.

The site code numbering system is that given in SEG special publication International Gravity Measurements (Woollard and Rose, 1963). CW - Pendulum observation sites established by Woollard and Rose; WA - Airports; WH - Harbor sites; others as indicated.

Table A-1

Comparison of Woollard and Rose (1963)

Gravimeter Values with IGSN 71 Values

on an Areal Basis in Alaska

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| WA 321 | Adak 'J' | 981.4420 | .427 64 | 14.36 | |
| WA 322 | Allaket | 982.3583 | .344 05* | 14.25 | |
| WA 323 | Anchorage | 981.9204 | .905 86* | 14.54 | |
| | | | .905 82* | 14.58 | |
| USC Pend | Anchorage 'A' | 981.9400 | .925 19 | 14.81 | |
| WA 474 | Elmendorf AFB 'J' | 981.9382 | .923 56 | 14.64 | |
| WA 324 | A[illegible]ette Is. | 981.5274 | .513 28* | 14.12 | |
| WA 325 | Barter Is.'J' | 982.5954 | .581 56 | 13.84 | |
| | | | .581 55* | 13.85 | |
| WA 327 | Beaver | 982.3315 | .316 40* | 15.10 | |
| WA 329 | Bettles | 982.3842 | .369 45* | 14.75 | |
| WA 331 | Cape Lisburne | 982.5304 | .516 59* | 13.81 | |
| WA 332 | Cape Newenham | 981.8247 | .809 97* | 14.73 | |
| WA 337 | Chitina | 981.9492 | .929 47* | 19.73 | Site? |
| WA 338 | Circle | 982.3049 | .290 09* | 14.81 | |
| WA 339 | Cordova | 981.9579 | .934 09* | 14.81 | |
| WA 340 | Demarcation Pt. | 982.5672 | .552 93* | 14.27 | |
| WA 341 | Dillingham | 981.8658 | .854 74* | 11.06 | Site? |
| WA 342 | Dutch Harbor | 981.5530 | .538 58* | 14.42 | |
| GW 6 | Fairbanks "A" | 982.2462 | .231 71 | 14.49 | |
| | | | .231 70* | 14.50 | |
| GW 27 | Fairbanks "B" | 982.2444 | .229 91 | 14.49 | |
| Abs | Fairbanks "E" | 982.2495 | .235 00 | 14.50 | |
| WA 279 | Fairbanks "J" | 982.2464 | .231 97 | 14.43 | |
| WA 349 | Flat | 982.0936 | .078 91* | 14.69 | |
| WA 351 | Fort Yukon | 982.3580 | .343 40* | 14.60 | |
| WA 355 | Gulkana | 981.9314 | .916 95* | 14.45 | |
| WA 357 | Homer | 981.8824 | .868 49* | 13.91 | |
| WA 358 | Hughes | 982.3341 | .319 45* | 14.65 | |

Table A-1

Alaska (cont.)

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| WA 360 | Huslia | 982.3213 | .307 90* | 13.40 | Site? |
| WA 361 | Iliamna | 981.9030 | .888 39* | 14.61 | |
| WA 363 | Juneau | 981.7680 | .753 64* | 14.36 | |
| WA 364 | Kenai | 981.8378 | .822 78* | 15.02 | |
| WA 365 | King Salmon | 981.8426 | .827 99* | 14.61 | |
| WA 368 | Kotzebue | 982.4141 | .339 73* | 14.37 | |
| WA 369 | Koyuk | 982.2929 | .278 51* | 14.39 | |
| WA 370 | Koyukuk | 982.2801 | .266 34* | 13.76 | |
| WA 372 | Livengood | 982.2725 | .258 23* | 14.27 | |
| WA 375 | McGrath | 982.1284 | .113 59* | 14.81 | |
| WA 377 | Munchumina | 982.1545 | .139 98* | 14.52 | |
| WA 380 | Nome | 982.2749 | .259 20* | 15.70 | Site? |
| WA 382 | Palmer | 981.9816 | .967 99* | 13.61 | |
| GW 105 | Point Barrow "A" | 982.6996 | .685 18 | 14.42 | |
| | | | .685 17* | 14.43 | |
| WA 280 | Point Barrow "K" | 982.6998 | .685 21 | 14.59 | |
| WA 385 | Ruby | 982.2376 | .252 55* | 15.05 | |
| WA 387 | Shemya | 981.5088 | .492 08* | 16.72 | Site? |
| WA 388 | Skagway | 981.7736 | .758 80* | 14.80 | |
| WA 390 | Stevens Village | 982.3244 | .309 06* | 15.34 | |
| WA 393 | Tanana | 982.2782 | .263 70* | 14.50 | |
| WA 395 | Teller | 982.3119 | .297 15* | 14.75 | |
| WA 396 | Tin City | 982.3141 | .299 63* | 14.47 | |
| WA 281 | Umiat | 982.5444 | .529 65* | 14.75 | |
| WA 397 | Umnak Is. | 981.5176 | .502 73* | 14.87 | |
| WA 398 | Unalakleet | 982.2178 | .202 83* | 14.97 | |
| WA 404 | Yakataga | 981.9037 | .891 54* | 12.16 | Site |
| WA 405 | Yakutat | 981.8371 | .822 49* | 14.61 | |

Table A-2

**Comparison of Woollard and Rose Gravimeter Values**

**and IGSN 71 Values on an Areal Basis in Canada**

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| ALBERTA | | | | |
| GW 32 | Calgary "A" | 980.8281 | 813 55 | 14.55 |
| WA 180 | Calgary "J" | 980.8288 | 814 25 | 14.55 |
| GW 25 | Edmonton "B" | 981.1678 | 153 16 | 14.64 |
| | | | 153 09* | 14.71 |
| GW 5 | Edmonton "C" | 981.1672 | 152 79 | 14.41 |
| WA 181 | Edmonton "K" | 981.1729 | 158 38 | 14.52 |
| WA 282 | RCAF NAMAO "M" | 981.1803 | 165 84 | 14.46 |
| Camb | Grande Prairie "A" | 981.3180 | 303 22 | 14.78 |
| | | | 303 20* | 14.80 |
| GW 10 | Grande Prairie "B" | 981.3175 | 302 85 | 14.65 |
| WA 183 | Grande Prairie "J" | 981.3158 | 300 99 | 14.81 |
| GW 33 | Lethbridge "A" | 981.7589 | 744 62 | 14.28 |
| | | | 744 61* | 14.29 |
| GW 12 | Lethbridge "C" | 981.7584 | 744 18 | 14.22 |
| WA 184 | Lethbridge "J" | 981.7538 | 739 15 | 14.65 |
| BRITISH COLOMBIA | | | | |
| Camb | Fort Nelson "A" | 981.6828 | 668 17* | 14.63 |
| WA 182 | Fort Nelson "J" | 981.6929 | 678 39 | 14.51 |
| GW 27 | Fort St. John "A" | 981.4059 | 391 21 | 14.69 |
| WA 284 | Fort St. John "J" | 981.4055 | 390 78 | 14.72 |
| | | | 390 79* | 14.71 |
| WA 285 | Liard River | 981.7041 | 689 47* | 14.63 |
| WA 286 | Prince George | 981.1772 | 162 14* | 15.06 |
| WA 288 | Sikanni Chief | 981.3941 | 379 46* | 14.64 |
| Dom Obs | Vancouver "A" | 980.9352 | 920 68 | 14.52 |
| | | | 920 68* | 14.52 |
| WA 186 | Vancouver "J" | 980.9299 | 915 41 | 14.49 |

Table A-2 (cont.)

**Canada (cont.)**

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| LABRADOR | | | | | |
| WA 291 | Goose Bay "J" | 981.3078 | 292 81 | 14.99 | |
| | "K" | | 293 24 | 14.56 | |
| MANITOBA | | | | | |
| WA 292 | Churchill | 981.7675 | 752 87* | 14.63 | |
| WA 80 | Winnipeg "J" | 980.9924 | 977 56 | 14.84 | |
| NEWFOUNDLAND | | | | | |
| WA 294 | Argentia | 980.8539 | 840 15* | 13.75 | site? |
| WA 297 | St. Johns | 980.8369 | 822 25* | 14.65 | |
| WA 298 | Stephenville | 980.9318 | 916 77* | 15.03 | |
| NORTHWEST TERRITORY | | | | | |
| WA 301 | Aklavik | 982.4902 | 475 59* | 14.61 | |
| WA 302 | Cape Parry | 982.6220 | 607 40* | 14.60 | |
| | Cornwallis Is. | | | | |
| WA 303 | Resolute Bay | 982.8624 | 848 74 | 13.66 | |
| | | | 848 73* | 13.67 | |
| | Ellesmere Land | | | | |
| WA 304 | Alert | 983.1417 | 117 96* | 23.74 | site? |
| WA 305 | Eureka | 983.0275 | 014 09 | 13.41 | |
| | | | 014 06* | 13.44 | |
| | Ellef Rignes Is. | | | | |
| WA 306 | Isachsen | 983.0597 | 045 10* | 14.60 | |
| | Prince Patrick Is. | | | | |
| WA 307 | Mould Bay | 982.9333 | .918 70* | 14.60 | |
| WA 308 | Yellowknife | 982.0245 | .009 88* | 14.62 | |
| | Victoria Island | | | | |
| WA 309 | Cambridge Bay | 982.5182 | .503 59* | 14.61 | |
| ONTARIO | | | | | |
| Dom Obs | Ottawa "A" | 980.6208 | 606 14 | 14.66 | |
| GW 53 | Ottawa "B" | 980.6217 | 607 10 | 14.60 | |
| | | | 607 07* | 14.63 | |
| WA 310 | Ottawa "L" | 980.6187 | 604 14 | 14.56 | |
| WA 79 | Toronto | 980.4298 | 415 09 | 14.71 | |
| | | | 415 09* | 14.71 | |

Table A-2 (cont.)

Canada (cont.)

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| QUEBEC | | | | |
| WA 77 | Montreal "N" | 980.6437 | 629 24 | 14.46 |
| WA 185 | Quebec | 980.7405 | 725 92* | 14.58 |
| YUKON | | | | |
| WA 311 | Burwash | 981.7543 | 739 67* | 14.63 |
| WA 312 | Dawson | 982.5223 | 507 69* | 14.61 |
| WA 313 | Shingle Point | 982.5223 | 507 69* | 14.61 |
| WA 314 | Stokes Point | 982.5702 | 555 59* | 14.61 |
| WA 315 | Teslin Lake | 981.7270 | 712 37* | 14.63 |
| Dom Obs | Watson Lake "A" | 981.7150 | 700 39 | 14.61 |
| WA 476 | Watson Lake "J" | 981.7143 | 699 98 | 14.32 |
| GW 26 | Whitehorse "B" | 981.7486 | 734 25 | 14.35 |
| WA 188 | Whitehorse "J" | 981.7487 | 734 25 | 14.45 |

Table A-3

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal basis in the United States

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| ALABAMA | | | | |
| WA 82 | Mobile | 979.3396 | 324 69* | 14.91 |
| ARIZONA | | | | |
| WA 194 | Douglas | 979.0576 | 042 90* | 14.70 |
| WA 195 | Flagstaff | 979.1427 | 128 35* | 14.35 |
| WA 196 | Nogales | 979.0701 | 055 24* | 14.86 |
| WA 2 | Phoenix | 979.4918 | 476 83* | 14.97 |
| WA 197 | Prescott | 979.2406 | 226 39* | 14.21 |
| WA 3 | Tucson | 979.2277 | 213 01* | 14.69 |
| WA 198 | Winslow | 979.2777 | 263 55* | 14.15 |
| ARKANSAS | | | | |
| WA 4 | Little Rock "J" | 979.7245 | 709 40 | 15.10 |
| CALIFORNIA | | | 709 40* | 15.10 |
| WA 202 | Fairfield | 979.9898 | 975 38* | 14.42 |
| WA 83 | Los Angeles | 979.5946 | 580 00* | 14.60 |
| WA 207 | Red Bluff | 980.1046 | 090 06* | 14.54 |
| WA 85 | San Diego "J" | 979.5369 | 522 36 | 14.54 |
| | | | 522 38* | 14.52 |
| WA 453 | San Diego "K" | 979.5336 | 518 54 | 15.06 |
| GW 54 | San Francisco "A" | 979.9867 | 972 13 | 14.57 |
| | | | 972 37* | 14.33 |
| WA 86 | San Francisco "K" | 979.9883 | 973 75 | 14.55 |
| WA 87 | San Francisco "J" | 979.9885 | 973 81 | 14.69 |
| COLORADO | | | | |
| GW 39 | Denver "B" | 979.6117 | 597 10 | 14.60 |
| X cntr | Denver "D" | 979.6114 | 596 53 | 14.87 |
| WA 89 | Denver "J" | 979.6333 | 618 97 | 14.33 |
| WA 90 | Denver "K" | 979.6327 | 618 48 | 14.22 |
| CONNECTICUT | | | | |
| WU 8 | New Haven | 980.3163 | 301 50* | 14.80 |

Table A-3 (cont.)

United States (cont.)

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| | DISTRICT OF COLOMBIA | | | | |
| US 337 | Commerce Pier "A" | 980.1188 | .104 29 | -14.51 | |
| U337A | Commerce 14th St. "C" | 980.1182 | .103.63 | -14.57 | |
| GW 2 | CIW Dept.Terr.Mag."D" | 980.1006 | .086 05 | -14.55 | |
| Old NBS | NBS Abs Conn Av. "E" | 980.0995 | .084 86 | -14.64 | |
| WA 493 | Natl. Airport "K" | 980.1089 | .094 40 | -14.50 | |
| | FLORIDA | | | | |
| WA 484 | Daytona Beach "J" | 979.2771 | .262 50 | -14.60 | |
| WA 217 | Jacksonville "J" | 979.3856 | .370 97 | -14.63 | |
| GW 116 | Key West "A" | 978.9692 | .954 46 | -14.54 | |
| WH 39 | Key West NB "J" | 978.9686 | .954 07 | -14.53 | |
| GW 115 | Miami Mar. Lab. "A" | 979.0356 | .020 95 | -14.65 | |
| WH 3 | Miami Port "B" | 979.0356 | .020 96 | -14.64 | |
| WA 278 | Miami Intl. AP "J" | 979.0528 | .038 29 | -14.51 | |
| WA 11 | Miami EAL "L" | 979.0543 | .039 57 | -14.73 | |
| WA 13 | Orlando AP "J" | 979.2187 | .204 09 | -14.61 | |
| WA 464 | Orlando McCoy AFB "L" | 979.2004 | .185 84 | -14.56 | |
| WA 461 | Pompano Beach "N" | 979.0864 | .071 58 | -14.82 | |
| WA 462 | St. Augustine "O" | 979.3418 | .327 21 | -14.59 | |
| WA 16 | Tampa "J" | 979.2044 | .189 59 | -14.81 | |
| | | | .189 53* | -14.87 | |
| WA 460 | Vero Beach "J" | 979.1737 | .159 04 | -14.66 | |
| WA 17 | West Palm Beach "J" | 979.1333 | .118 70 | -14.60 | |
| | GEORGIA | | | | |
| | Atlanta, Emory U. "A" | 979.5380 | .523 57 | -14.43 | |
| WA 470 | Atlanta AP "J" | 979.5206 | .506 31 | -14.29 | |
| WA 469 | Atlanta AP "K" | 979.5211 | .506.90 | -14.20 | |
| WA 18 | Brunswick "J" | 979.4494 | .434 74 | -14.66 | |
| WA 19 | Columbus | 979.5125 | .507 31* | -15.19 | Site? |
| WA 20 | Macon | 979.5321 | .517 48* | -14.62 | |
| WA 99 | Savannah "J" | 979.4977 | .483 08 | -14.62 | |
| | IDAHO | | | | |
| WA 21 | Boise "J" | 980.2082 | .193 64 | -14.56 | |

Table A-3(cont.)

United States (cont.)

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| | ILLINOIS | | | | |
| GW 23 | Chicago "A" | 980.2873 | .272 62 | -14.68 | |
| WA 101 | Midway "J" | 980.2864 | .271 79 | -14.61 | |
| WA 23 | Springfield | 980.0821 | .067 43* | -14.67 | |
| | INDIANA | | | | |
| WA 103 | West Lafayette | 980.1469 | .132 40* | -14.50 | |
| | IOWA | | | | |
| WA 220 | Boone | 980.3226 | .307 59* | -15.01 | |
| W 24 | Cedar Rapids | 980.2519 | .237 35* | -14.55 | |
| WA 221 | Cleremont | 980.3787 | .363 93* | -14.77 | |
| WA 222 | Davenport | 980.2521 | .236 60* | -15.50 | site? |
| WA 25 | Des Moines | 980.1984 | .184 41* | -13.99 | site? |
| WA 228 | Sioux City "J" | 980.3073 | .292 98 | -14.32 | |
| | KANSAS | | | | |
| GW 52 | Beloit | 979.9981 | .983 59* | -14.51 | |
| WA 106 | Wichita "J" | 979.8408 | .826 26 | -14.54 | |
| | KENTUCKY | | | | |
| WA 107 | Lexington | 979.8988 | .884 12* | -14.68 | |
| WA 26 | Louisville "J" | 979.9585 | .943 67 | -14.83 | |
| | LOUISIANA | | | | |
| WA 108 | Baton Rouge | 979.3637 | .349 01* | -14.69 | |
| WA 230 | Lake Charles | 979.3324 | .317 71* | -14.69 | |
| WA 110 | New Orleans "J" | 979.3298 | .314 94 | -14.86 | |
| | MAINE | | | | |
| WA 231 | Augusta | 980.5372 | .522 54* | -14.66 | |
| WA 457 | Bangor "J" | 980.5912 | .576 45 | -14.75 | |
| WA 458 | Caribou "J" | 980.7322 | .717 49 | -14.71 | |
| WA 232 | Greenville | 980.5895 | .574 84* | -14.66 | |
| | MARYLAND | | | | |
| WA 112 | Baltimore "M" | 980.1034 | .088 67 | -14.73 | |
| | MASSACHUSETTS | | | | |
| WA 114 | Boston "O" | 980.4036 | .389 24 | -14.36 | |
| WA 472 | Hyannis | 980.3400 | .325 41* | -14.59 | |

Table A-3(cont.)

United States (cont.)

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| GW 77A | Woods Hole BM | 980.3271 | .312 49* | -14.61 | |
| MICHIGAN | | | | | |
| | Detroit | | | | |
| WA 116 | "K" Willow Run AP | 980.3188 | .304 08 | -14.72 | |
| WA 496 | "L" Metropolitan AP | 980.3190 | .304 46 | -14.54 | |
| MINNESOTA | | | | | |
| WA 118 | Minneapolis "K" | 980.5950 | .580 92 | -14.08 | Site? |
| MISSOURI | | | | | |
| WA 120 | Kansas City "J" | 979.9998 | .985 46 | -14.34 | |
| WA 121 | St. Louis "J" | 980.0042 | .989 52 | -14.68 | |
| MONTANA | | | | | |
| GW 25 | Billings "A" | 980.3710 | .356 37 | -14.63 | |
| WA 122 | Billings AP "K" | 980.3717 | .357 37 | -14.33 | |
| WA 123 | Butte | 980.1744 | .159 88* | -14.52 | |
| GW 34 | Cutbank "B" | 980.6085 | .593 83 | -14.67 | |
| WA 242 | Glendive | 980.6371 | .622 44* | -14.66 | |
| GW 4 | Great Falls "A" | 980.[illegible]269 | .512 30 | -14.60 | |
| WA 482 | Great Falls "J" | 980.5137 | .499 11 | -14.59 | |
| WA 243 | Malmstrom AFB "K" | 980.[illegible]1 | .514 52 | -14.58 | |
| WA 31 | Helena | 980.3778 | .363 50* | -14.30 | |
| WA 32 | Kalispell | 980.5818 | .567 39* | -14.41 | |
| WA 244 | Miles City | 980.5230 | .508 55* | -14.45 | |
| WA 127 | Missoula | 980.4440 | .429 45* | -14.55 | |
| WA 245 | Stanford | 980.4369 | .422 55* | -14.35 | |
| NEVADA | | | | | |
| WA 39 | Ely | 979.4946 | .480 08* | -14.52 | |
| WA 450 | Indian Springs | 979.5560 | .541 16* | -14.84 | Site |
| WA 128 | Las Vegas "J" | 979.6049 | .590 37 | -14.53 | |
| WA 40 | Tonopah | 979.4767 | .462 25* | -14.45 | |
| NEW JERSEY | | | | | |
| WA 248 | Newark | 980.2415 | .226 89* | -14.61 | |
| GW 78 | Princeton "A" | 980.1783 | .163 73 | -14.57 | |
| GW 78A | Princeton Univ "B" | 980.1776 | .163 06 | -14.54 | |

Table A-3(cont.)

United States (cont.)

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| WA 42 | McGuire AFB "J" | 980.2128 | .198 36 | -14.44 | |
| | NEW MEXICO | | | | |
| WA 130 | Albuquerque "K" | 980.2081 | .193 51 | -14.59 | |
| | NEW YORK | | | | |
| | New York City | | | | |
| WA 252 | Idlewild "R" | 980.2273 | .212 59 | -14.71 | |
| WA 133 | Kennedy "K" | 980.2261 | .211 35 | -14.75 | |
| WA 132 | La Guardia "S" | 980.2825 | .267 77 | -14.73 | |
| WA 14 | Navy Yard "Q" | 980.2721 | .257 36 | -14.74 | |
| WA 134 | Syracuse "K" | 980.3968 | .382 08 | -14.72 | |
| | NORTH CAROLINA | | | | |
| WA 44 | Charlotte "J" | 979.7283 | .713 43 | -14.87 | site? |
| WA 46 | New Bern | 979.7286 | .714 16* | -14.44 | |
| | NORTH DAKOTA | | | | |
| WA 49 | Bismarck "J" | 980.6274 | .612 75 | -14.65 | |
| WA 50 | Fargo "J" | 980.7270 | .712 66 | -14.34 | |
| WA 51 | Jamestown | 980.6540 | .639 34* | -14.66 | |
| WA 447 | Pembina | 980.9166 | .902 48* | -14.12 | site? |
| | OHIO | | | | |
| WA 137 | Cleveland | 980.2322 | .217 56* | -14.64 | |
| WA 22 | Columbus (Univ.) "C" | 980.0961 | .081 40 | -14.70 | |
| WA 138 | Columbus "J" | 980.0791 | .064 21 | -14.89 | site? |
| | OKLAHOMA | | | | |
| GW 52 | Tulsa Univ. | 979.7661 | .751 46* | -14.64 | |
| | OREGON | | | | |
| WA 140 | Eugene | 980.5148 | .500 23* | -14.57 | |
| WA 55 | Pendleton | 980.5117 | .496 76* | -14.94 | |
| WA 142 | Portland "J" | 980.6483 | .633 62 | -14.68 | |
| WA 56 | Salem | 980.5837 | .569 03* | -14.67 | |
| | PENNSYLVANIA | | | | |
| WA 145 | Pittsburgh "J" | 980.0993 | .084 46 | -14.84 | |
| | SOUTH CAROLINA | | | | |
| GW 90 | Charleston "A" | 979.5509 | .536 35 | -14.55 | |

Table A-3 (cont.)

United States (cont.)

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| WA 449 | Charleston AP "J" | 979.5667 | .552 16 | -14.54 |
| WA 148 | Charleston AP "K" | 979.5668 | .552 27 | -14.53 |
| WA 147 | Charleston MATS | 979.5675 | .552 98 | -14.52 |
| WA 57 | Florence "J" | 979.6851 | .670 34 | -14.76 |
| | SOUTH DAKOTA | | | |
| WA 59 | Aberden | 980.5438 | .529 19* | -14.61 |
| U 1200 | Huron (BM) | 980.4530 | .438 59* | -14.41 |
| WA 262 | Sioux Falls "J" | 980.3616 | .347 49 | -14.11 |
| WA 64 | Spearfish | 980.2521 | .237 98* | -14.12 |
| | TENNESSEE | | | |
| WA 149 | Chatanooga | 979.6505 | .635 82* | -14.68 |
| | TEXAS | | | |
| GW 50 | Amarillo "A" | 979.4235 | .409 11 | -14.39 |
| WA 67 | Amarillo AP "J" | 979.4234 | .408 87 | -14.53 |
| WA 263 | Beaumont | 979.3149 | .300 21* | -14.69 |
| WA 264 | Childress | 979.4881 | .473 95* | -14.15 |
| WA 266 | Dalhart | 979.4402 | .425 51* | -14.69 |
| WA 154 | Dallas "J" | 979.5131 | .498 41 | -14.69 |
| GW 18 | Houston "A" | 979.2983 | .283 72 | -14.58 |
| WA 159 | Houston "J" | 979.2932 | .278 66 | -14.64 |
| GW 18-A | Houston "B" | 979.2983 | .283 72 | -14.58 |
| WA 160 | Laredo "J" | 979.0792 | .064 61 | -14.59 |
| WA 68 | Lubbock "J" | 979.3228 | .308 36 | -14.44 |
| GW 40 | San Antonio "A" | 979.1975 | .182 73 | -14.77 |
| WA 162 | San Antonio "J" | 979.1976 | .182 86 | -14.74 |
| WA 161 | San Antonio "L" | 979.1973 | .182 57 | -14.73 |
| | UTAH | | | |
| WA 209 | Ogden, Hill AFB "J" | 979.8005 | .786 08 | -14.42 |
| WA 163 | Salt Lake City "L" | 979.8070 | .782 44 | -14.56 |
| WA 164 | Vernal | 979.6686 | .653 80* | -14.80 |
| | VERMONT | | | |
| WA 165 | Burlington | 980.5181 | .503 73* | -14.37 |
| | VIRGINIA | | | |
| WA 73 | Richmond "J" | 979.9534 | .938 66 | -14.74 |

Table A-3 (cont.)

United States (cont.)

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| WA 168 | Roanoke | 979.8076 | .793 11 | -14.49 | |
| | WASHINGTON | | | | |
| GW 104 | Seattle "A" | 980.7388 | .724 34 | -14.46 | |
| WA 170 | Seattle AP "K" | 980.7765 | .762 02 | -14.48 | |
| WA 173 | Spokane "K" | 980.6463 | .631 78 | -14.52 | |
| | WEST VIRGINIA | | | | |
| WA 174 | Charleston | 979.9259 | .911 29* | -14.61 | |
| WA 274 | Huntington | 979.9519 | .937 65* | -13.85 | site? |
| | WISCONSIN | | | | |
| GW 3 | Madison "A" | 980.3689 | .354 22 | -14.68 | |
| WA 76 | Madison AP "J" | 980.3725 | .357 82 | -14.68 | |
| | WYOMING | | | | |
| GW 37 | Casper Pend. | 979.9558 | .941 33* | -14.47 | |
| WA 177 | Casper AP "J" | 979.9562 | .941 59 | -14.61 | |
| GW 38 | Cheyenne "A" | 979.7006 | .686 18 | -14.42 | |
| GW 37 | Cheyenne "B" | 979.7008 | .686 30 | -14.50 | |
| WA 178 | Cheyenne AP "J" | 979.7008 | .686 23 | -14.57 | |
| WA 276 | Douglas | 979.9533 | .938 62* | -14.68 | |
| GW 36 | Sheridan "A" | 980.2264 | .212 05 | -14.35 | |
| WA 179 | Sheridan "J" | 980.2265 | .212 14 | -14.36 | |

Table A-4

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal Basis in Mexico

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| | BAJA CALIFORNIA SUR | | | |
| WA 432 | Santa Rosalita | 978.1079 | .092 45* | -15.45 |
| | CAMPECHE | | | |
| WA 406 | Campeche | 978.6519 | .636 71* | -15.19 |
| WA 409 | Ciudad del Carmen | 978.5676 | .552 80* | -14.80 |
| | CHIAPAS | | | |
| WA 435 | Tapachula | 978.3186 | .304 97* | -13.63 |
| | CHIHUAHUA | | | |
| WA 417 | Ciudad Juarez | 979.0697 | .055 26* | -14.44 |
| WA 429 | Parral | 978.5372 | .523 84* | -13.36 |
| | COAHUILA | | | |
| WA 430 | Saltillo | 978.5785 | .563 70* | -14.80 |
| WA 437 | Torrean | 978.6399 | .625 50* | -14.40 |
| | DISTRITO FEDERAL | | | |
| GW 43 | Mexico Un. "A" | 977.9414 | .926 50 | -14.90 |
| GW 41 | Tacubaya "D" | 977.9419 | .927 15 | -14.75 |
| WA 189 | Int'l. AP "J" | 977.9701 | .955 42 | -14.68 |
| WA 489 | Int'l. AP "L" | 977.9705 | .955 99 | -14.51 |
| GW 42 | Paso de Cortes "A" | 977.5711 | .556 36 | -14.74 |
| GW 42B | Cortes Mon "C" | 977.6536 | .638 32 | -15.28 Site? |
| | JALISCO | | | |
| WA 413 | Guadalajara | 978.2203 | .207 66* | -12.64 Site? |
| | NAYARIT | | | |
| WA 436 | Tepic | 978.4682 | .453 22* | -14.98 |

Table A-4 (cont.)

Mexico (cont.)

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| NUEVO LEON | | | | |
| GW 21 | Monterrey "A" | 978.8055 | .790 69 | -14.81 |
| WA 190 | Monterrey AP "J" | 978.8617 | .847 05 | -14.65 |
| OAXACA | | | | |
| WA 435 | Tehuantepec | 978.4190 | .404 04* | -14.96 |
| SAN LUIS POTOSI | | | | |
| WA 431 | San Luis Potosi AP "J" | 978.2096 | .194 70 | -14.90 |
| WA 492 | San Luis Potosi "K" | 978.2097 | .194 78 | -14.92 |
| WA 433 | Tamuin | 978.7589 | .744 43* | -14.47 |
| SINOLA | | | | |
| WA 411 | Culican | 978.9315 | .917 64* | -13.86 |
| WA 420 | Los Mochis | 978.0199 | .005 75* | -14.15 |
| TABASCO | | | | |
| WA 441 | Villahermosa | 978.5278 | .513 39* | -14.41 |
| TAMAULIPAS | | | | |
| WA 426 | Nuevo Laredo "K" | 979.0770 | .062 55 | -14.45 |
| VERA CRUZ | | | | |
| WA 440 | Vera Cruz | 978.5613 | .545 89* | -15.41 |
| YUCATAN | | | | |
| WA 423 | Merida | 978.6990 | .683 51* | -15.49 |

Table A-5

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal basis in Central America and the West Indies

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| CENTRAL AMERICA | | | | |
| CANAL ZONE | | | | |
| WH 1056 | Balboa Rodman NB "R" | 978.2376 | .222 54 | -15.06 |
| WH 1057 | Cristobal | 978.2536 | .238 56* | -15.04 |
| GW 92 | Ft. Clayton Pend. "A" | 978.2417 | .226 70 | -15.00 |
| US Pend | Ft. Clayton Pend. "O" | 978.2391 | .224 00 | -15.10 |
| WA 4004 | Albrook AFB "S" | 978.2427 | .227 72 | -14.98 |
| COSTA RICA | | | | |
| WA 4049 | Golfito | 978.2389 | .223 98* | -14.92 |
| WA 4043 | Liberia | 978.1967 | .181 79* | -14.91 |
| WA 4046 | Los Chiles | 978.2443 | .229 37* | -14.93 |
| WA 4045 | Nicoya | 978.2728 | .257 87* | -14.93 |
| WA 4007 | San Jose "K" | 978.9792 | .964 36 | -14.84 |
| GUATEMALA | | | | |
| WA 4019 | Chahel | 978.3717 | .356 74* | -14.96 |
| WA 4022 | Dos Lagunas | 978.4820 | .467 02* | -14.98 |
| WA 4011 | Guatemala C. "K" | 977.9815 | .966 80 | -14.70 |
| WA 4021 | Santo Torbido | 978.4020 | .387 04* | -14.9[illegible] |
| HONDURAS | | | | |
| WA 4034 | Ruinas de Sopan | 978.2140 | .199 39* | -14.61 |
| WA 4012 | Tegucigalpa | 978.0869 | .072 32* | -14.58 |
| NICARAGUA | | | | |
| WA 4013 | Managua | 978.2858 | .270 92* | -14.88 |
| | Managua "K" | 978.2858 | .270 76 | -15.04 |
| WA 4036 | San Juan del Sur | 978.2609 | .245 98* | -14.92 |
| WA 4037 | Siuna | 978.3258 | .310 56* | -15.24 |
| PANAMA | | | | |
| WA 4050 | David | 978.1616 | .146 60* | -15.00 |
| WA 4014 | Panama, Tocumen AP | 978.2665 | .251 44* | -15.06 |

Table A-5 (cont.)

Central American and West Indies (cont.)

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| WEST INDIES | | | | |
| CUBA | | | | |
| WA 4009 | Guantanamo "K" | 978.7451 | .730 55 | -14.55 |
| LEEWARD ISLANDS | | | | |
| WA 4001 | Antiqua "B" | 978.6544 | .638 91 | -15.48 |
| PUERTO RICO | | | | |
| WA 4015 | Ramey AFB "K" | 978.6602 | .645 01 | -15.19 ? |
| WA 4016 | San Juan "J" | 978.6845 | .669 88 | -14.62 |
| TRINIDAD | | | | |
| WA 4003 | Port au Spain "J" | 978.1622 | .146 88 | -15.32 |

Table B

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal basis in South America

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| ARGENTINA | | | | |
| WA 6001 | Bahia Blanca "K" | 980.0683 | .052 78 | +15.52 |
| | Bahia Blanca | .0683 | .052 88* | +15.42 |
| GW 98A | Buenos Aires "A" | 979.7048 | .690 03 | +14.77 |
| Univ | Meter. Obs. "C" | 979.7060 | .691 16 | +14.84 |
| WA 6002 | Ezeisa AP "K" | 979.7317 | .716 75 | +14.95 |
| WA 6005 | Comodoro Riva. "K" | 980.6634 | .648 03 | +15.37 |
| WA 6004 | Cordoba "K" | 979.3271 | .312 34 | +14.76 |
| Univ Base | La Plata "D" | 979.7517 | .736 85 | +14.85 |
| WA 6007 | Mar del Plata | 980.0181 | .002 73 * | +15.37 |
| WA 6008 | Oran "K" | 978.6381 | .623 48 | +14.62 |
| WA 6010 | Rio Gallegos "K" | 981.2066 | .191 38 | +15.22 |
| | Rio Gallegos | .2066 | .191 34* | +15.26 |
| WA 6011 | Rio Grande "L" | 981.4330 | .417 22 | +15.78 |
| WA 6012 | Salta "K" | 978.4985 | .483 95 | +14.55 |
| WA 6013 | San Julian "L" | 981.0137 | .997 64 | +16.06 |
| WA 6014 | Santa Cruz | 981.0465 | .030 24* | +16.26 |
| WA 6015 | Santiago del Estero | 979.0986 | .084 33* | +14.27 |
| WA 6016 | Tartagal | 978.5938 | .578 79* | +15.01 |
| WA 6017 | Trelew "K" | 980.4539 | .438 70 | +15.20 |
| WA 6018 | Tucuman "K" | 978.9060 | .982 06 | +13.94 |
| Pend | Ushuaia Pent. "A" | 981.4807 | .465 39 | +15.31 |
| BOLIVIA | | | | |
| WA 6165 | Acension | 978.3905 | .375 55* | +14.95 |
| WA 6167 | Camiri | 978.3535 | .338 73* | +14.77 |
| WA 6173 | Cabija | 978.1685 | .153 60* | +14.90 |
| WA 6162 | Cochabamba | 977.7945 | .779 94* | +14.56 |
| GW 95 | La Paz "A" | 977.4671 | .452 19 | +14.91 |
| WA 6134 | Braniff AP "K" | 977.3528 | .338 00 | +14.80 |
| WA 6020 | Pan Am AP "L" | 977.3487 | .334 02 | +14.68 |
| WA 6175 | Magdalena | 978.3308 | .315 92* | +14.88 |

Table B (cont.)

South America (cont.)

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| WA 6172 | Riberalta | 978.2378 | .222 88* | +14.92 |
| WA 6169 | San Ignacio, M | 978.3337 | .318 76* | +14.94 |
| WA 6166 | San Javier | 978.3367 | .321 82* | +14.88 |
| WA 6174 | San Juaquin | 978.2975 | .282 52* | +14.98 |
| WA 6170 | San Ana | 978.3388 | .323 85* | +14.95 |
| WA 6021 | Santa Cruz "K" | 978.3639 | .349 07 | +14.83 |
| WA 6141 | Santa Cruz "J" | 978.3643 | .349 44 | +14.86 |
| WA 6163 | Sucre | 977.7915 | .776 70* | +14.80 |
| WA 6168 | Trinidad | 978.3374 | .322 70* | +14.70 |
| BRAZIL | | | | |
| WA 6022 | Acu | 978.0839 | .069 02* | +14.88 |
| WA 6023 | Alegrete | 979.2926 | .277 41* | +15.19 |
| WA 6024 | Anapolis | 978.1489 | .134 01* | +14.89 |
| WA 6026 | Aracati | 978.0979 | .083 02* | +14.88 |
| WA 6027 | Aracatuba | 978.5808 | .565 80* | +15.00 |
| WA 6028 | Aragarcas | 978.3196 | .304 66* | +14.94 |
| WA 6030 | Araquari | 978.2764 | .261 47* | +14.93 |
| WA 6031 | Bage | 979.4128 | .397 58* | +15.22 |
| GW 108 | Belem "A" | 978.0374 | .022 24 | +15.16 |
| WA 6032 | Belem AP "K" | 978.0342 | .018 97 | +15.23 |
| WH 1012 | Tide Gage "O" | 978.0397 | .024 59 | +15.11 |
| WH 1055 | Pier "N" | 978.0399 | .024 63 | +15.27 |
| WA 6033 | Belo Horizonte | 978.4003 | .385 50* | +14.80 |
| WA 6035 | Brasilia "K" | 978.1013 | .086 07 | +15.23 |
| WA 6142 | Brasilia "J" | 978.1001 | .084 92 | +15.18 |
| WA 6036 | Caceres | 978.3968 | .381 84* | +14.96 |
| WA 6037 | Campo Grande | 978.5065 | .491 52* | +14.98 |
| WA 6039 | Campos "J" | 978.7326 | .717 49 | +15.11 |
| WA 6041 | Caravelas "J" | 978.5270 | .511 46 | +15.54 |
| WA 6042 | Carolina "J" | 978.0461 | .031 11 | +14.99 |
| WA 6029 | Conceicao A | 978.0449 | .030 03* | +14.87 |
| WA 6043 | Cruz Alta | 979.1207 | .105 55* | +15.15 |
| WA 6044 | Cruzeiro do Sul | 978.1081 | .093 21* | +14.89 |
| WA 6045 | Cuiaba | 978.3590 | .344 05* | +14.95 |

Table B (cont.)

South America (cont.)

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| WA 6046 | Curitiba | 978.7895 | .774 45* | +15.05 | |
| WA 6047 | Esplanada | 978.2614 | .246 48* | +14.92 | |
| WA 6048 | Fazenda Si Juan | 978.4820 | .467 02* | +14.98 | |
| WA 6051 | Florinapolis "J" | 979.1338 | .118 93 | +14.87 | |
| WA 6053 | Fortaleza "J" | 978.0822 | .067 81 | +14.39 | site? |
| WA 6055 | Goiania "J" | 978.2403 | .225 40 | +14.90 | |
| WA 6056 | Grajau | 977.9848 | .969 95* | +14.85 | |
| WA 6057 | Guajara Mirim | 978.2172 | .202 28* | +14.92 | |
| WA 6058 | Iquassu Falls | 978.9191 | .904 01* | +14.99 | |
| WA 6059 | Ilheus | 978.4617 | .446 87* | +14.83 | |
| WA 6060 | Imperatriz | 978.0195 | .004 39* | +15.11 | |
| WA 6154 | Itacoatiara | 978.0165 | .001 64* | +14.86 | |
| WA 6061 | Joao Pessoa "J" | 978.1443 | .129 03 | +15.27 | |
| | | 978.1443 | .129 18* | +15.12 | |
| WA 6062 | Livramento | 979.3357 | .320 50* | +15.20 | |
| WA 6155 | Londrina | 978.6518 | .636 77* | +15.03 | |
| WA 6063 | Maceio | 978.1429 | .128 07* | +14.83 | |
| WA 6064 | Manaus "J" | 978.0213 | .006 16 | +15.14 | |
| | | 978.0213 | .006 27* | +15.03 | |
| WA 6065 | Maraba | 978.0364 | .021 53* | +14.87 | |
| WA 6066 | Mossoro | 978.0926 | .077 45* | +15.15 | |
| WA 6067 | Natal | 978.1151 | .099 85* | +15.25 | |
| WA 6068 | Paracatu | 978.2596 | .244 67* | +14.93 | |
| WA 6069 | Parana | 978.1699 | .155 00* | +14.90 | |
| WA 6070 | Parnaiba | 978.0372 | .020 62* | +16.58 | site? |
| WA 6071 | Paulo Afonso | 978.0951 | .081 79* | +14.31 | |
| WA 6072 | Peixe | 978.1981 | .183 03* | +15.07 | |
| WA 6074 | Porto Alegre "J" | 979.3158 | .300 78 | +15.02 | |
| WA 6159 | Porto Guaira | 978.8091 | .794 03* | +15.07 | |
| WA 6075 | Porto Nacional "J" | 978.1605 | .145 44 | +15.06 | |
| WA 6076 | Porto Seguro | 978.4661 | .451 12* | +14.98 | |
| WA 6077 | Porto Velho | 978.1444 | .129 51* | +14.89 | |
| WA 6079 | Recife "J" | 978.1665 | .151 25 | +15.25 | |

Table B (cont.)

South America (cont.)

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| WH 1059 | Harbor "M" | 978.1777 | .162 52 | +15.18 | |
| WA 6080 | Rio Branco | 978.1582 | .143 30* | +14.90 | |
| GW 109 | Rio de Janeiro "A" | 978.8047 | .789 90 | +14.80 | |
| WA 6082 | Galeao AP "J" | 978.7978 | .783 05 | +14.75 | |
| WA 6081 | S. Dumont "L" | 978.8084 | .793 55 | +14.85 | |
| WH 1060 | Pier Praca N. "O" | 978.8076 | .792 78 | +14.82 | |
| WA 6083 | Salvador "J" | 978.3443 | .329 43 | +14.87 | |
| WA 6084 | Santa Maria | 979.2771 | .261 91* | +15.19 | |
| WA 6153 | Santarem | 978.0468 | .031 93* | +14.87 | |
| WA 6086 | Sao Borja | 979.2040 | .188 84* | +15.16 | |
| WA 6151 | Sao Luis | 977.9901 | .975 52* | +14.58 | |
| WA 6088 | Sao Mateus | 978.5719 | .556 90* | +15.00 | |
| WA 6090 | Sao Paulo "M" | 978.6508 | .635 56 | +15.24 | site? |
| | | 978.6508 | .636 23* | +14.57 | |
| WA 6091 | Sena Madureira | 978.1569 | .142 00* | +14.90 | |
| WA 6092 | Tarauaca | 978.1403 | .125 41* | +14.89 | |
| WA 6149 | Tefe "J" | 978.0472 | .031 88 | +15.32 | |
| WA 6093 | Teresina | 978.0320 | .01710* | +14.90 | |
| WA 6094 | Tocantinapolis | 978.0440 | .029 13* | +14.87 | |
| WA 6095 | Tocantinia | 978.1092 | .094 31* | +14.89 | |
| WA 6096 | Tres Lagos | 978.5717 | .556 70* | +15.00 | |
| WA 6097 | Uberaba | 978.3609 | .345 39* | +15.51 | |
| WA 6158 | Uruguiana | 979.3075 | .292 31* | +15.19 | |
| WA 6100 | Villa Bella | 978.3408 | .325 85* | +14.95 | |
| WA 6101 | Vitoria "J" | 978.6537 | .638 25 | +15.45 | |
| WA 6102 | Xabantina | 978.2837 | .268 77* | +14.93 | |
| WA 6103 | Xapuri | 978.1898 | .174 89* | +14.91 | |
| CHILE | | | | | |
| GW 99 | Antofogasta "A" | 978.9045 | .889 52 | +14.98 | |
| WA 6105 | Cerro Moreno AP "K" | 978.8853 | .870 30 | +15.00 | |
| WA 6135 | Old AP "L" | 978.8830 | .868 04 | +14.96 | |
| WA 6106 | Arica, Old AP "N" | 978.5111 | .495 82 | +15.28 | |
| WA 6144 | Intl AP "L" | 978.4939 | .478 54 | +15.36 | |

Table B (cont.)

South America (cont.)

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| WA 6160 | Concepcion | 979.9698 | .954 44* | +15.36 | |
| WA 6147 | Puerto Montt "J" | 980.2976 | .282 22 | +15.38 | |
| WA 6148 | Chameza AP "K" | 980.3041 | .288 74 | +15.36 | |
| GW 97 | Punta Arenas "A" | 981.3159 | .300 49 | +15.41 | |
| WA 6108 | Chabunco AP "K" | 981.3122 | .296 70 | +15.50 | |
| WA 6136 | Chabunco AP "L" | 981.3130 | .297 61 | +15.39 | |
| WH 1019 | Port Adm. "N" | 981.3363 | .320 81 | +15.49 | |
| GW 96 | Santiago "A" | 979.4294 | .414 11 | +15.29 | |
| WA 6110 | Los Cerillos AP "K" | 979.4500 | .434 68 | +15.32 | |
| WA 6109 | Los Cerillos "J" | 979.4493 | .434 24 | +15.06 | |
| WH 1020 | Valparaiso Pier "K" | 979.6362 | .620 87 | +15.33 | |
| WH 1058 | Valpariso L. H. "L" | 979.6342 | .618 90 | +15.30 | |
| COLOMBIA | | | | | |
| WA 6111 | Barranquilla "J" | 978.2265 | .211 56 | +14.94 | |
| WH 1066 | Port "K" | 978.2393 | .224 27 | +15.03 | |
| GW 106 | Bogota "A" | 977.4049 | .390 11 | +14.79 | |
| WA 6112 | Techo AP "J" | 977.4017 | .386 91 | +14.76 | |
| WA 6145 | Eldorado AP "K" | 977.3954 | .380 59 | +14.81 | |
| WA 6113 | Cali "J" | 977.8197 | .804 89 | +14.81 | |
| WA 6114 | Cartagena | 978.1965 | .181 59* | +14.91 | |
| WA 6181 | Chafurray | 977.9887 | .973 84* | +14.81 | |
| WA 6116 | Ipiales | 977.2532 | .238 53* | +14.67 | |
| Pend | Medellin | 977.7547 | .740 66* | +14.24 | site? |
| WA 6118 | Pereira | 977.7740 | .759 20* | +14.80 | |
| WA 6119 | Popayan "K" | 977.5998 | .584 49 | +15.31 | site? |
| WA 6179 | San Juan | 977.8964 | .881 57* | +14.83 | |
| WA 6178 | Villavicencio | 977.8676 | .852 77* | +14.83 | |
| ECUADOR | | | | | |
| WA 6120 | Guayaquil "M" | 978.1391 | .123 71 | +15.39 | |
| WA 6146 | Guayaquil AP "K" | 978.1447 | .129 34 | +15.46 | |
| WA 1067 | Pier "N" | 978.0918 | .076 30 | +15.50 | |
| WA 6177 | Manta | 978.1017 | .086 81* | +14.89 | |
| GW 106 | Quito "A" | 977.2777 | .263 19 | +14.51 | |

Table B (cont.)

South America (cont.)

| | | Woollard and Rose | IGSN 71 | Diff |
|---|---|---|---|---|
| WA 6121 | Panagra AP "J" | 977.2860 | .271 44 | +14.56 |
| WA 6139 | Mariscal Sucre AP | 977.2849 | .270 38* | +14.52 |
| | FRENCH GUIANA | | | |
| WA 6122 | Cayenne | 978.0387 | .023 83* | +14.87 |
| | GUYANA (British Guiana) | | | |
| WA 6104 | Georgetown "K" | 978.0909 | .075 55 | +15.35 |
| WA 6143 | New Term. "J" | 978.0911 | .075 70 | +15.40 |
| WH 1062 | Harbor "L" | 978.1179 | .102 48 | +15.42 |
| | PARAGUAY | | | |
| WA 6123 | Assuncion "J" | 978.9583 | .943 12 | +15.18 |
| | PERU | | | |
| WA 6124 | Arequipa "K" | 977.7165 | .701 73 | +14.77 |
| WA 6125 | Iquitos "J" | 978.0876 | .072 11 | +15 49 |
| GW 93 | Lima "A" | 978.2830 | .267 94 | +15.06 |
| WA 6126 | Limatambo AP "J" | 978.2791 | .264 08 | +15.02 |
| WA 6140 | Callao Intl "K" | 978.3072 | .292 18 | +15.02 |
| WH 1068 | Callao Pier "M" | 978.3127 | .297 79 | +14.91 |
| WA 6176 | Pucallpa | 978.0550 | .040 13* | +14.87 |
| WA 6127 | Talara | 978.1336 | .118 64* | +14.96 |
| | SURINAM | | | |
| WA 6128 | Paramaribo "J" | 978.0471 | .033 50 | +13.60 site? |
| | URAGUAY | | | |
| WA 6129 | Montevideo "K" | 979.7465 | .731 56 | +14.94 |
| | VENEZUELA | | | |
| WA 6130 | Barcelona | 978.1505 | .135 63* | +14.87 |
| WA 6193 | Caicara | 978.1247 | .111 08* | +13.62 site? |
| WA 6191 | Calabazo | 978.1679 | .153 69* | +14.21 site? |
| GW 107 | Caracas "A" | 978.0399 | .024 72 | +15.18 |
| WA 6131 | Maiquetia AP "K" | 978.2460 | .231 06 | +14.94 |
| WH 1071 | La Guayra Hrb. "L" | 978.2522 | .237 24 | +14.96 |
| WA 6185 | Casigua | 978.1170 | .102 12* | +14.88 |
| WA 6190 | Coro | 978.2374 | .222 48* | +14.92 |

Table B (cont.)

South America (cont.)

| | | Woollard and Rose | IGSN 71 | Diff | |
|---|---|---|---|---|---|
| WA 6133 | Maturia "J" | 978.0112 | .966 31 | +14.89 | |
| WA 6187 | Merida | 977.7506 | .735 92* | +14.68 | |
| WA 6194 | Puerto Paez | 978.0818 | .066 92* | +14.88 | |
| WA 6184 | San Antonio | 977.9430 | .927 57* | +15.43 | site? |
| WA 6192 | San Fernando Apure | 978.1412 | .126 30* | +14.90 | |

Table C

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal Basis in Europe

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| CYPRUS | | | | |
| Pend. | Nicosia | 979.8492 | .83449* | +14.71 |
| DENMARK | | | | |
| GW 64 | Copenhagen "B" | 981.5577 | .54319 | +14.51 |
| WA 5004 | Kastrup AP "J" | 981.5573 | .54275 | +14.55 |
| WA 5059 | Kastrup AP "L" | 981.5568 | .54226 | +14.54 |
| EIRE (Ireland) | | | | |
| Pend. Base | Dublin (Dunsink Obs.) | 981.3891 | .37478* | +14.32 |
| FINLAND | | | | |
| Pend. Base | Helsinki "A" | 981.9152 | .90059 | +14.61 |
| WA 5019 | Seutula AP "S" | 981.9248 | .91009 | +14.71 |
| FRANCE | | | | |
| WA 5022 | Bordeaux | 980.5816 | .56694* | +14.66 |
| WA 5023 | Marseille "J" | 980.4880 | .47355 | +14.45 |
| GW 114 | Paris "A" | 980.9409 | .92597 | +14.93 |
| Gm Base | Obs. "B" | 980.9434 | .92865 | +14.75 |
| Nat'l Base | Obs. "E" | 980.9432 | .92829 | +14.91 |
| WA 5058 | Orly AP "N" | 980.9160 | .90101 | +14.99 |
| WA 5024 | Le Bourget AP "J" | 980.9502 | .93534 | +14.86 |
| ITALY | | | | |
| WA 5032 | Naples "R" | 980.2568 | .24204 | +14.76 |
| GW 61 | Rome "A" | 980.3639 | .34923 | +14.67 |

Table C (cont.)

Europe (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| Nat'l Base Rome "B" | | 980.3619 | .34722 | +14.68 |
| | Roca de Papa Obs. "C" | 980.1929 | .17843 | +14.47 |
| WA 5033 | Ciampino Est "J" | 980.3489 | .33427 | +14.63 |
| WA 5034 | Ciampino Ovest "M" | 980.3478 | .33319 | +14.61 |
| WA 5060 | Fiumicino Int'l "N" | 980.3765 | .36176 | +14.74 |
| NETHERLANDS | | | | |
| WA 5036 | Amsterdam "J" | 981.2882 | .27340 | +14.80 |
| Pend. | DeBilt Obs. | 981.2693 | .25456* | +14.74 |
| NORWAY | | | | |
| GW 117 | Bodo "A" | 982.3873 | .37265 | +14.65 |
| WA 5037 | Airport "J" | 982.3876 | .37297 | +14.63 |
| GW 118 | Hammerfest "A" | 982.6324 | .61762 | +14.78 |
| WH 1045 | Indrefjord "J" | 982.6301 | .61548 | +14.62 |
| GW 68 | Oslo "A" | 981.9272 | .91261 | +14.59 |
| WA 5038 | Fornebu AP "J" | 981.9367 | .91620 | +14.50 |
| WA 5039 | Tromso "K" | 982.5710 | .55711 | +13.89 site? |
| Pend. | Trondheim "A" | 982.1614 | .14674 | +14.66 |
| WA 5040 | Vaernes AP "K" | 982.1523 | .13779 | +14.51 |
| PORTUGAL | | | | |
| GW 110 | Lisbon "A" | 980.0903 | .07573 | +14.57 |
| WA 5041 | Airport "K" | 980.0796 | .06512 | +14.48 |
| SPAIN | | | | |
| Pend. | Madrid Astro. Obs. "A" | 979.9812 | .96652 | +14.68 |
| Gm Base | IGC "C" | 979.9703 | .95561 | +14.69 |

Table C (cont.)

Europe (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| WA 5049 | Barajas AP "J" | 979.9988 | .98414 | +14.64 |
| WA 5051 | Torrejon AFB "M" | 980.0072 | .99251 | +14.69 |
| SWEDEN | | | | |
| Pend. | Stockholm "A" | 981.8465 | .83143 | +15.07 |
| WA 5053 | Bromma AP "J" | 981.8455 | .83066 | +14.84 |
| SWITZERLAND | | | | |
| WA 5054 | Geneva "J" | 980.5889 | .57444 | +14.46 |
| Pend. | Zurich Geod. Inst. "A" | 980.6670 | .65213 | +14.87 |
| WA 5055 | Kloten AP "J" | 980.6871 | .67218 | +14.92 |
| UNITED KINGDOM | | | | |
| Pend.Sta. | Aberdeen Univ. | 981.6996 | .68482* | +14.98 |
| Pend.Sta. | Cambridge Univ. | 981.2688 | .25394* | +14.86 |
| Pend.Sta. | Edinburgh Obs. "A" | 981.5839 | .56897 | +14.93 |
| WA 5047 | Prestwick AP "J" | 981.5784 | .56351 | +14.89 |
| WA 5046 | Prestwick MATS "K" | 981.5758 | .56113 | +14.67 |
| WA 5044 | Glasgow "N" | 981.6018 | .58692 | +14.88 |
| GW 67 | Teddington "A" | 981.1966 | .18178 | +14.82 |
| WA 5012 | London AP (1) "J" | 981.2003 | .18558 | +14.72 |
| WA 5013 | Old Term. "M" | 981.2017 | .18704 | +14.66 |
| Pend. | York | 981.4183 | .40380* | +14.50 |
| WEST GERMANY | | | | |
| GW 63 | Bad Harzburg "A" | 981.1803 | .16550 | +14.80 |
| GW 63A | Braunschweig "C" | 981.2668 | .25184 | +14.96 |

Table C (cont.)

Europe (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| GW 62 | Frankfurt "A" | 981.0610 | .04632 | +14.68 |
| WA 5028 | Airport "J" | 981.0571 | .04243 | +14.67 |
| WA 5064 | Hamburg "J" | 981.3943 | .37969 | +14.61 |
| WA 5063 | Hannover "K" | 981.2875 | .27261 | +14.88 |

Table D

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal Basis in Africa

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| ALGERIA | | | | |
| WA 1001 | Algiers "J" | 979.9057 | .89139 | +14.31 |
| EGYPT | | | | |
| WH 1023 | Alexandria Port | 979.4331 | .41921* | +13.89 site? |
| GW 69 | Cairo "B" | 979.2915 | .27676 | +14.74 |
| WA 1002 | Farouk AP "L" | 979.3160 | .30125 | +14.75 |
| WA 1004 | Port Said "K" | 979.4528 | .43764 | +15.16 |
| WH 1026 | Suez | 979.3069 | .29221* | +14.69 |
| ETHIOPIA | | | | |
| WA 1006 | Addis Ababa "L" | 977.4783 | .46396 | +14.34 |
| GW 76 | Asmara "A" | 977.8194 | .80545 | +13.95 |
| WA 1005 | Mun. AP "J" | 977.8224 | .80826 | +14.14 |
| WA 1007 | Debra Markus | 977.5107 | .49416* | +15.54 site? |
| WA 1008 | Gondar | 977.7060 | .65126* | +14.74 |
| WA 1009 | Tesseni "J" | 978.1902 | .17580 | +14.40 |
| GAMBIA | | | | |
| WA 1011 | Bathurst "J" | 978.3535 | .33875 | +14.55 |
| GHANA | | | | |
| GW 112 | Accra "A" | 978.1059 | .09141 | +14.49 |
| WA 1012 | Airport "J" | 978.1153 | .10052 | +14.78 |
| GUINEA | | | | |
| WA 1036 | Conakry "J" | 978.2264 | .21094 | +15.46 |

Table D (cont.)

Africa (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| KENYA | | | | |
| GW 71 | Nairobi "A" | 977.5403 | .52607 | +14.23 |
| Camb. | Bullard (L) "C" | 977.5279 | .51375 | +14.15 |
| WA 1014 | Eastleigh "J" | 977.5430 | .52877 | +14.23 |
| WA 1015 | West Civil "K" | 977.5357 | .52151 | +14.19 |
| LIBYA | | | | |
| WA 1019 | Benghazi | 979.5264 | .51170* | +14.70 |
| GW 60 | Tripoli "A" | 979.5876 | .57272 | +14.88 |
| WA 1021 | Idris AP "L" | 979.5379 | .52300 | +14.90 |
| WA 1020 | Wheeler AFB "K" | 979.5876 | .57274 | +14.86 |
| MALAGASY | | | | |
| WA 9006 | Tananarive "J" | 978.2166 | .20242 | +14.18 |
| MOROCCO | | | | |
| WA 1023 | Casablanca "J" | 979.6428 | .62796 | +14.84 |
| WA 1026 | Tangier "J" | 979.7492 | .73401 | +15.19 site? |
| MOZAMBIQUE | | | | |
| WA 1027 | Beira | 978.6252 | .61049* | +14.71 |
| WA 1028 | Lourenco Marques | 979.0527 | .03801* | +14.69 |
| NIGERIA | | | | |
| WA 1029 | Kano "J" | 978.1357 | .12092 | +14.78 |
| RHODESIA | | | | |
| WA 1042 | Bulawayo "J" | 978.2921 | .27754 | +14.56 |
| WA 1043 | Salisbury "J" | 978.1484 | .13414 | +14.26 |
| Pend. | Salisbury "A" | 978.1481 | .13365 | +14.45 |
| Pend. | Victoria Falls | 978.2314 | .21689* | +14.51 |

Table D (cont.)

Africa (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| | SENEGAL | | | |
| GW 111 | Dakar Mbour "B" | 978.3852 | .37039 | +14.81 |
| WA 1010 | Yof AP "J" | 978.4772 | .46242 | +14.78 |
| | SOMALI | | | |
| WA 1041 | Mogadiscio | 978.0779 | .06318* | +14.72 |
| | SOUTH AFRICA | | | |
| WA 1055 | Bloemfontein | 978.8537 | .83900* | +14.70 |
| GW 74 | Capetown "A" | 979.6473 | .63271 | +14.59 |
| Pend. | Royal Obs. "B" | 979.6535 | .63893 | +14.57 |
| WA 1057 | Malam AP "J" | 979.6462 | .63145 | +14.75 |
| WA 1056 | Wingfield AP "L" | 979.6494 | .63484 | +14.56 |
| GW 73 | Johannesburg "A" | 978.5495 | .53546 | +14.04 |
| WA 1062 | L. Smuts AP "K" | 978.5503 | .53610 | +14.20 |
| WA 1063 | Kimberley "J" | 978.8881 | .87371 | +14.39 |
| WA 1067 | Port Elizabeth | 978.6514 | .63571* | +15.69 site? |
| Pend. | Pretoria "A" | 978.6296 | .61530 | +14.30 |
| WA 1071 | Uppington | 978.9831 | .97040 | +14.70 |
| | SOUTHWEST AFRICA | | | |
| WA 1065 | Ohopoho | 978.2136 | .19887* | +14.73 |
| WA 1070 | Tsumeb | 978.2209 | .20619* | +14.71 |
| WA 1022 | Windhoek | 978.3210 | .30629* | +14.71 |
| | SUDAN | | | |
| GW 70 | Khartoum "B" | 978.3034 | .28867 | +14.73 |
| GW 70A | Univ. Pend. "A" | 978.3033 | .28864 | +14.66 |
| WA 1045 | Airport "L" | 978.3034 | .28865 | +14.75 |

Table D (cont.)

Africa (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| WA 1047 | Port Sudan "K" | 978.6404 | .62599 | +14.41 |
| | TANZANIA | | | |
| WA 1048 | Dar es Salaam "K" | 978.1165 | .10011 | +16.39 site? |
| WA 1049 | Dodoma | 977.7535 | .73930* | +14.20 |
| WA 1050 | Mbeya "K" | 977.6840 | .66989 | +14.11 |
| WA 1051 | Moshi "K" | 977.7720 | .75788 | +14.12 |
| WA 1052 | Tabora "J" | 977.6844 | .66995 | +14.45 |
| | TUNISIA | | | |
| WH 1054 | Sfax Harbor | 979.7267 | .71202* | +14.68 |
| WA 1053 | Tunis | 979.9061 | .89992* | +16.18 site? |
| | UGANDA | | | |
| WA 1054 | Entebbe "J" | 977.7241 | .70984 | +14.26 |
| | ZAIRE (CONGO) | | | |
| CW 113 | Leopoldville "A" | 977.9146 | .89982 | +14.78 |
| WA 1037 | Int'l. AP "J" | 977.9518 | .93713 | +14.67 |
| WA 1038 | Ndjili AP "M" | 977.9429 | .92820 | +14.70 |
| | ZAMBIA (N. RHODESIA) | | | |
| WA 1030 | Abercorn "J" | 977.6707 | .65662 | +14.08 |
| WA 1031 | Kasama "J" | 977.7877 | .77354 | +14.16 |
| WA 1033 | Lasapa "J" | 978.0534 | .03932 | +14.08 |
| WA 1034 | Ndola "K" | 977.9126 | .89830 | +14.30 |

Table E

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal Basis in Southwest Asia and South Asia

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| | BAHREIN | | | |
| WA 2002 | Muharraq | 979.0147 | .99963 * | +15.07 |
| | CEYLON | | | |
| | Colombo | | | |
| Pend. | Met. Obs. "B" | 978.1328 | .11724 | +15.56 |
| Pend. | Fr. Consul "C" | 978.1403 | .12454 | +15.76 |
| WA 2004 | Ratmalana AP "J" | 978.1323 | .11690 | +15.40 |
| | INDIA | | | |
| WA 2010 | Amritzar "J" | 979.3484 | .33506 | +13.34 site? |
| Pend. | Bangladore "A" | 978.0294 | .01389 | +15.51 |
| WA 2011 | Bangladore "J" | 978.0387 | .02314 | +15.56 |
| WA 2013 | Calcutta "J" | 978.8077 | .79281 | +14.89 |
| Nat'l Base | Dehra Dun "A" | 979.0636 | .04909 | +14.51 |
| WA 2016 | Hyderabad "J" | 978.3347 | .31958 | +15.12 |
| WA 2017 | Jammu | 979.3041 | .29004* | +14.06 |
| Pend. | Madras "A" | 978.2818 | .26658 | +15.25 |
| WA 2018 | Madras AP "J" | 978.2804 | .26516 | +15.24 |
| GW 59 | New Delhi "A" | 979.1363 | .12155 | +14.75 |
| WA 2019 | Palam AP "J" | 979.1341 | .11938 | +14.72 |
| WA 2020 | Willingdon AP "K" | 979.1379 | .12316 | +14.74 |
| WA 2021 | Srinagar | 979.0443 | .03013 | +14.17 |

Table E (cont.)

Southwest Asia and South Asia (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| IRAN | | | | |
| WA 2023 | Tehran "J" | 978.4491 | .43068 | +18.42 site? |
| IRAQ | | | | |
| WA 2024 | Ain Zalah | 979.7840 | .76933* | +14.67 |
| WA 2025 | Baghdad | 979.5469 | .53222* | +14.68 |
| WA 2026 | Basrah | 979.3240 | .30931* | +14.69 |
| WA 2027 | Kirkuk | 979.5991 | .64272* | +14.68 |
| KUWAIT | | | | |
| WA 2049 | Al Kuwait | 979.2688 | .25411* | +14.69 |
| LEBANON | | | | |
| Pend. | Beirut "A" | 979.6909 | .67625 | +14.65 |
| WA 2050 | Khalde $AP_1$ "J" | 979.6934 | .67864 | +14.76 |
| WA 2051 | Khalde $AP_2$ "K" | 979.6922 | .67744 | +14.76 |
| PAKISTAN | | | | |
| WA 2059 | Karachi | 978.9620 | .94730* | +14.70 |
| QATAR | | | | |
| WA 2064 | Dukhan | 978.9528 | .93810* | +14.70 |
| SAUDI ARABIA | | | | |
| WA 2067 | Abu Hadriyah | 979.1084 | .09370* | +14.70 |
| WA 2068 | Dhahran | 978.9990 | .98430* | +14.70 |
| WA 2069 | Jidda | 978.7556 | .75222* | +13.38 site? |
| WA 2070 | Ras Al Mishab | 979.1696 | .15491* | +14.69 |

Table E (cont.)

Southwest Asia and South Asia (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| TRUCIAL STATES | | | | |
| WA 2075 | Sharjah | 978.9026 | .88790* | +14.70 |
| TURKEY | | | | |
| WA 2076 | Ankara "M" | 979.9500 | .93548 | +14.52 |
| WA 2077 | Izmir | 980.0231 | .00842* | +14.68 |
| YEMEN | | | | |
| WA 2001 | Aden "J" | 978.3179 | .30432 | +13.58 site? |

Table F

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal Basis in Southeast Asia and East Asia

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| | CAMBODIA | | | |
| WA 2003 | Phnom Penh "J" | 978.2390 | .22308 | +15.82 |
| | FEDERATION OF MALAYSIA | | | |
| | Sabah (North Borneo) | | | |
| WA 2054 | Jesselton | 978.1279 | .11318* | +14.72 |
| WA 2055 | Labuan Is. | 978.0960 | .08128* | +14.72 |
| WA 2056 | Sandakan | 978.0914 | .07668* | +14.72 |
| | Sarawak | | | |
| WA 2065 | Kuching | 978.0763 | .06158* | +14.72 |
| WA 2066 | Sibu | 978.0790 | .06428* | +14.72 |
| | HONG KONG | | | |
| GW 101 | Am. Consulate "A" | 978.7677 | .75231 | +15.39 |
| WA 2008 | Kai-Tak AP "J" | 978.7730 | .75766 | +15.34 |
| Pend. | Kowloon Roy. Obs. "B" | 978.7712 | .75585 | +15.35 |
| | INDONESIA | | | |
| WA 3045 | Djakarta | 978.1644 | .14968* | +14.72 |
| | NEW CALEDONIA | | | |
| WA 7016 | Tontouta | 978.8590 | .84430* | +14.70 |
| | NEW GUINEA AREA and BISMARCK ARCHIPELAGO | | | |
| | New Britain Is. | | | |
| WA 3011 | Rabaul | 978.1643 | .15001* | +14.29 |

Table F (cont.)

Southeast Asia and East Asia (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| | New Ireland Is. | | | |
| WA 3081 | Kavieng | 978.1668 | .15208* | +14.72 |
| | Papua | | | |
| WA 3069 | Port Moresby "J" | 978.2129 | .19833 | +14.57 |
| | Terr. of New Guinea | | | |
| WA 3084 | Aitape | 978.1707 | .15598* | +14.72 |
| WA 3077 | Goroka | 977.6994 | .68467* | +14.73 |
| WA 3076 | Lae | 978.0140 | .99614* | +17.86 site? |
| WA 3078 | Madang | 977.9701 | .95504* | +15.06 |
| WA 3086 | Vanima | 978.1997 | .18498* | +14.72 |
| WA 3079 | Wewak | 978.0965 | .08158* | +14.92 |
| | West Irian | | | |
| WA 3098 | Biak Is. | 978.1237 | .10898* | +14.72 |
| WA 3097 | Hollandia | 978.1721 | .15737* | +14.73 |
| WA 3099 | Manokwari | 978.0869 | .07218* | +14.72 |
| WA 3068 | Noemfoor Is. | 978.1409 | .12618* | +14.72 |
| WA 3096 | Sarmi | 978.1461 | .13137* | +14.73 |
| WA 3101 | Sorong | 978.1401 | .12537* | +14.73 |
| | PHILIPPINES | | | |
| GW 58 | Clark AFB "A" | 978.3969 | .38230 | +14.60 |
| WA 2061 | Clark MATS "J" | 978.3965 | .38183 | +14.67 |
| WA 2062 | Manila Intl. AP "K" | 978.3767 | .36192 | +14.78 |
| WH 1048 | Manila Pier "N" | 978.3562 | .34142 | +14.78 |

Table F (cont.)

| Southeast Asia and East Asia (cont.) | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| SINGAPORE | | | | |
| GW 102 | Univ. Malaya "A" | 978.0815 | .06668 | +14.82 |
| Pend. | Raffles Mus. "B" | 978.0809 | .06604 | +14.86 |
| WA 2071 | Changi RAF "E" | 978.0801 | .06521 | +14.89 |
| WA 2072 | Kallang AP "J" | 978.0817 | .06681 | +14.89 |
| WA 2073 | Paya Lebar "L" | 978.0804 | .06561 | +14.79 |
| SOLOMON ISLANDS | | | | |
| WA 3075 | Honiara | 978.2742 | .25984* | +14.36 |
| WA 3073 | Munda | 978.2541 | .23938* | +14.72 |
| TAIWAN | | | | |
| WA 2007 | Taipei "J" | 978.9725 | .95946 | +13.04 site? |
| THAILAND | | | | |
| WA 2074 | Bangkok "J" | 978.3297 | .31485 | +14.85 |
| VIETNAM | | | | |
| WA 2078 | Hanoi | 978.6888 | .67409* | +14.71 |
| WA 2079 | Hue | 978.4367 | .42198* | +14.72 |
| WA 2080 | Nha-Trang | 978.2624 | .24769* | +14.71 |
| WA 2081 | Saigon "J" | 978.2300 | .21509 | +14.91 |
| | EAST ASIA | | | |
| JAPAN | | | | |
| WA 2032 | Itani "J" | 979.7171 | .70375 | +13.35 site ? |
| WA 2033 | Iwakuni | 979.6522 | .63752* | +14.68 |
| Pend. | Kyoto "A" | 979.7216 | .70727 | +14.33 |

Table F (cont.)

Southeast Asia and East Asia (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| WA 2034 | Misawa | 980.3200 | .30534* | +14.66 |
| WA 2035 | Tachikawa "S" | 979.7880 | .77398 | +14.02 |
| GW 103 | Tokyo "A" | 979.8016 | .78722 | +14.38 |
| WA 2037 | Haneda AP "L" | 979.7736 | .75916 | +14.44 |
| GW 103 | Sapporo "B" | 980.4406 | .42735 | +13.25 |
| WA 2030 | Chitose AP "J" | 980.4405 | .42734 | +13.16 |
| SOUTH KOREA | | | | |
| WA 2045 | Pusan | 979.7780 | .77405* | +13.95 |
| WA 2047 | Seoul "K" | 979.9722 | .95847 | +13.73 |
| | Seoul "J" | .9722 | .95863 | +13.57 |
| OKINAWA | | | | |
| GW 100 | Kadena "A" | 979.1265 | .11222 | +14.28 |
| WA 2057 | Kadena MATS "J" | 979.1343 | .11992 | +14.38 |

Table G

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal Basis in Australia and New Zealand

| | | Woollard and Rose | IGSN 71 | Diff Mgal | |
|---|---|---|---|---|---|
| AUSTRALIA | | | | | |
| Pend. | Adelaide | 979.7243 | .709 20* | +15.10 | |
| WA 3003 | Alice Springs "J" | 978.6541 | .639 39 | +14.71 | |
| GW 85 | Brisbane "B" | 979.1695 | .155 16 | +14.34 | |
| GW 85 A | Univ. Seismic Sta. "A" | 979.1701 | .155 93 | +14.17 | |
| WA 3004 | Eagle Farm AP "J" | 979.1599 | .145 57 | +14.33 | |
| WA 3067 | Archer AP "K" | 979.1683 | .154 11 | +14.19 | |
| GW 87 | Cairns "A" | 978.5006 | .486 24 | +14.36 | |
| WA 3009 | Carnovan | 978.9447 | .928 83* | +15.87 | site? |
| WA 3010 | Ceduna | 979.4534 | .438 07* | +15.33 | |
| WA 3059 | Daly Waters | 978.3892 | .374 87 | +14.33 | * |
| GW 88 | Darwin "A" | 978.3140 | .299 55 | +14.45 | |
| WA 3058 | RAF Club "B" | 978.3164 | .301 92 | +14.48 | |
| WA 3014 | Airport "J" | 978.3154 | .300 93 | +14.47 | |
| WA 3015 | Derby | 978.5207 | .505 69* | +15.01 | |
| WA 3016 | Forrest | 979.3068 | .292 26* | +14.54 | |
| WA 3022 | Kalgoorlie | 979.2911 | .276 95* | +14.15 | |
| WA 3025 | Leigh Creek | 979.3204 | .306 76* | +13.64 | site? |
| WA 3026 | Mackay | 979.7339 | .720 77* | +13.13 | site? |
| WA 3027 | Maryborough "A" | 979.0219 | .007 32 | +14.58 | |
| GW 83 | Melbourne "A" | 979.9797 | .965 18 | +14.52 | |
| WA 3028 | Essendon AP "J" | 979.9628 | .948 21 | +14.59 | |
| | Kallista For. R. "S" | 979.9100 | .895 38 | +14.62 | |
| WA 3031 | Mount Isa "J" | 978.6190 | .604 41 | +14.59 | |
| WA 3033 | Oodnadatta | 979.1006 | .086 44* | +14.16 | |
| WA 3034 | Onslow | 978.7749 | .758 81* | +16.09 | site? |
| Pend | Perth Univ "A" | 979.3958 | .380 86 | +14.94 | |
| WA 3035 | Airport "K" | 979.4011 | .386 32 | +14.78 | |
| WA 3036 | Port Hedland | 978.6466 | .631 50* | +15.10 | |
| Pend | Rockhampton "A" | 978.8707 | .856 06 | +14.64 | |
| WA 3038 | Airport "J" | 978.8738 | .859 35 | +14.45 | |

Table G (cont.)

Australia - New Zealand (cont.)

| | | | IGSN 71 | Diff Mgal |
|---|---|---|---|---|
| GW 84 | Sydney "A" | 979.6863 | .671 86 | +14.44 |
| WA 3042 | Kingsford S. "J" | 979.6993 | .684 80 | +14.50 |
| WA 3041 | Rose Bay "L" | 979.6965 | .681 98 | +14.52 |
| WA 3042 | Tennant Creek | 978.5290 | .513 69* | +15.31 |
| GW 86 | Townsville "B" | 978.6247 | .610 43 | +14.27 |
| WA 3043 | Airport "C" | 978.6240 | .609 66 | +14.34 |
| WA 3044 | Wyndham | 978.4171 | .402 18* | +14.92 |
| | NEW ZEALAND | | | |
| Pend | Auckland Mus. "B" | 979.9487 | .934 11 | +14.59 |
| WA 3047 | Whenuapai AP "C" | 979.9408 | .926 04 | +14.76 |
| GW 79 | Christchurch "A" | 980.5089 | .494 29 | +14.61 |
| WA 3103 | Intl. AP "L" | 980.4962 | .481 59 | +14.61 |
| WA 3049 | Harewood AP "K" | 980.4962 | .481 47 | +14.73 |
| GW 89 | Dunedin "A" | 980.7424 | .727 53 | +14.87 |
| WA 3051 | Taieri AP "C" | 980.7366 | .721 75 | +14.85 |
| WA 3053 | Hastings | 980.0881 | .073 87* | +14.23 |
| GW 81 | Wellington "C" | 980.2934 | .279 09 | +14.31 |
| Pend Base | Wellington DSIR "A" | 980.2656 | .251 00 | +14 60 |
| WA 3058 | Rongotai AP "K" | 980.3064 | .292 01 | +14.39 |

Table H

Comparison of Woollard and Rose Gravimeter Values and IGSN 71

Values on an Areal Basis in Oceanic Islands

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| ATLANTIC AREA | | | | |
| ASCENSION | | | | |
| WA 7001 | Ascension Is. "J" | 978.2943 | .27939 | +14.91 |
| AZORES | | | | |
| WA 7002 | Lages, Terceira "J" | 980.1762 | .16142 | +14.67 |
| WA 7003 | Santa Maria "L" | 980.1167 | .10235 | +14.35 |
| BERMUDA | | | | |
| WA | Kindley "J" | 979.8093 | .79402 | +15.28 |
| WH 1007 | Biol. Sta. "P" | 979.8232 | .80807 | +15.13 |
| GREENLAND | | | | |
| WA 319 | Sondre Stromfjord "J" | 982.3843 | .37011 | +14.19 |
| WA 320 | Thule "J" | 982.9280 | .91375 | +14.25 |
| ICELAND | | | | |
| WA 7006 | Keflavik "K" | 982.2744 | .25943 | +14.97 |
| Natl Base | Reykjavik "A" | 982.2800 | .26496 | +15.04 |
| WA 7007 | Reykjavik AP "L" | 982.2784 | .26333 | +15.07 |
| WH 1035 | Reykjavik Pier "J" | 982.2813 | .26634 | +14.96 |
| PACIFIC AREA | | | | |
| FIJI | | | | |
| WA 7010 | Nandi "J" | 978.5471 | .53281 | +14.29 |
| WA 7009 | Suva | 978.6242 | .60939* | +14.81 |
| GUAM | | | | |
| WA 7011 | Agana NAS "J" | 978.5240 | .50903 | +14.97 |

Table H (cont.)

Oceanic Islands (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. mgal |
|---|---|---|---|---|
| HAWAIIAN ISLANDS | | | | |
| | Honolulu | | | |
| GW 55 | Bishop Mus. "B" | 978.9530 | .93835 | +14.65 |
| Pend. | Univ. "A" | 978.9593 | .94490 | +14.40 |
| WA 443 | Hickam AFB "J" | 978.9337 | .91914 | +14.56 |
| WA 444 | Old Int'l AP "S" | 978.9325 | .91810 | +14.40 |
| WA 7015 | Midway Is. "J" | 979.4993 | .48460 | +14.70 |
| WH 1041 | Pier "P" | 979.5077 | .49222 | +15.48 site? |
| LINE ISLANDS | | | | |
| WA 7013 | Johnston Is. | 978.7198 | .70514* | +14.66 |
| NEW CALEDONIA | | | | |
| WA 7016 | Tontouta | 978.8590 | .84430* | +14.70 |
| PHOENIX ISLANDS | | | | |
| WA 7017 | Canton Is. "J" | 978.2932 | .27880 | +14.40 |
| SAMOA | | | | |
| WA 7019 | Pago Pago "J" | 978.6407 | .62616 | +14.54 |
| SOCIETY ISLANDS | | | | |
| WA 7020 | Bora Bora | 978.6703 | .65559* | +14.71 |
| WA 7022 | Papeete "J" | 978.7086 | .69353 | +15.07 |
| TONGA | | | | |
| WA 7023 | Fua-Amotu AP | 978.8722 | .85749* | +14.71 |
| WAKE | | | | |
| WA 7024 | Wake Is. "J" | 978.8814 | .86656 | +14.84 |

Table H (cont.)

Oceanic Islands (cont.)

| | | Woollard and Rose | IGSN 71 | Diff. Mgal |
|---|---|---|---|---|
| | WALLIS ISLAND | | | |
| WA | Wallis Is. | 978.5215 | .50679* | +14.71 |
| | INDIAN OCEAN AREA | | | |
| WA 9004 | Cocos (Keeling Is.) "J" | 978.4687 | .45454 | +14.16 site? |
| WA 9005 | Heard Island | 981.4778 | .46318* | +14.62 |
| WA 9017 | Kerguelen Is. | 981.0734 | .05876* | +14.64 |
| WA 9007 | Mauritius Is. | 978.8666 | .85221* | +14.39 |

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ABSTRACT

The history of improvements in the global standardization of gravity values since the advent of high range gravimeters in 1948 is reviewed. In particular the gravity base values given in SEG special publication International Gravity Measurements (Woollard and Rose, 1963) are evaluated against the most recent set of standardized gravity base values, The International Gravity Standardization Net, 1971 (Morelli et al, 1974). Adjunct IGSN 71 values prepared by the U.S. Defense Mapping Agency Aerospace Center (unpublished) are also used to give a more comprehensive worldwide comparison of values. The results for 787 comparisons of Woollard and Rose (1963) values and IGSN 71 values for the same sites indicate that, in general, there is no difference in gravity standard represented. However, there is a mean absolute datum difference of 14.7 mgal (standard deviation 0.25 mgal). As this value is the same as the difference in the IGSN 71 value for the Woollard and Rose primary base value at Madison, Wisconsin, it corroborates the independent assessment that there is, in general, no difference in gravity standard. However, examination of the data by geographic areas indicates that there are areal anomalous offsets in datum due presumably to undetected tares in the Woollard and Rose values, and also a departure in gravity standard of 0.2 mgal per 1000 mgal in both South America and Europe. As it was possible to establish specific areas in which the Woollard and Rose values are in apparent error relative to the IGSN 71 values as well as the nature and magnitude of the differences in values, it appears possible to use the more extensive worldwide network of Woollard and Rose base values to extend the IGSN 71 network with, in general, an absolute reliability of the order of ±0.15 mgal. As many of the existing gravity surveys are not tied to IGSN 71 bases, but are tied to Woollard and Rose bases, much of the existing gravity data in the world not on the new IGSN 71 gravity system could thus be integrated into the new international gravity system with sufficient reliability for most purposes. However, more precise gravity values on an absolute basis are required if gravity is to play a significant role in studying global tectonic movements and geodynamic processes.

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