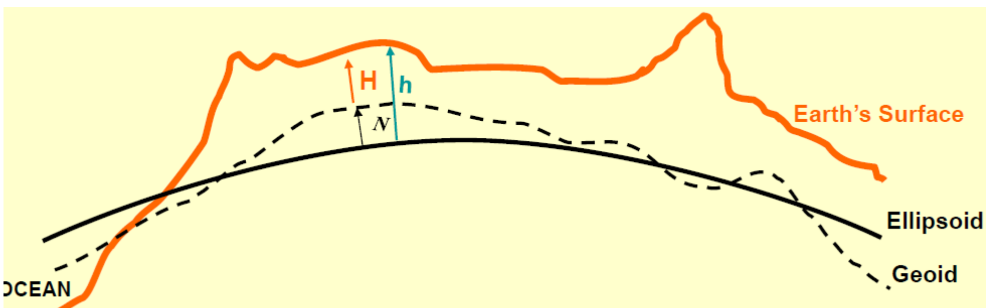
The study of Geodesy involves:

1st) Study three Surfaces:

1. Earth's Surface/ Topography
2. Geoid OCEAN
3. Ellipsoid

يتضمن موضوع الجيوديسي دراسة ثلاث امور:
من اجل الوصول الى الهدف (تعيين شكل وحجم الارض) نسلك الطريق من خلال:
1. دراسة السطوح study the surfaces
2. المواقع Positions
3. التوجيه Orientation



H (Leveling) = h (GPS) - ***N***

1) Geoid perpendicular to gravity
2) H = orthometric elevation (traditional leveling)
3) h = ellipsoidal height (GPS)
4) ***N*** = geoidal height (undulation, or h-H)

تجرى القياسات عادة على السطح الطوبوغرافي منسوبة الى سطح الجيؤيد وتحسب على سطح السفيرويد

For some parts, the surface of the geoid is below the reference ellipsoid, thus *N* is negative

It was stated earlier that **measurements** are made on the apparent or *topographic surface* of the Earth and it has just been explained that **computations** are performed on an *ellipsoid*. One other surface is involved in geodetic measurement: the *geoid*.

In geodetic surveying, the computation of the geodetic coordinates of points is commonly performed on a reference ellipsoid closely approximating the size and shape of the Earth in the area of the survey.

The actual measurements made on the surface of the Earth with certain instruments are however referred to the geoid. The ellipsoid is a mathematically defined regular surface with specific dimensions.

قيل في وقت سابق أن القياسات تتم على السطح الظاهر أو الطبوغرافي للأرض وقد تم شرحه للتو أن العمليات الحسابية تتم على ال *ellipsoid*. يشترك سطح آخر في القياس الجيوديسي: الجيؤيد.
في المسح الجيوديسي ، يتم حساب الإحداثيات الجيوديسية للنقاط بشكل شائع على *ellipsoid* مرجعي اقرب ما يمكن الى حجم وشكل الأرض في منطقة المسح.
القياسات الفعلية التي تم إجراؤها على سطح الأرض باستخدام أدوات مساحية معينة تنسب إلى الجيؤيد.

The geoid, on the other hand, coincides with that surface to which the oceans would conform over the entire Earth if free to adjust to the combined effect of the Earth's mass attraction (gravitation) and the centrifugal force of the Earth's rotation.

As a result of the uneven distribution of the Earth's mass, the geoidal surface is irregular and, since the ellipsoid is a regular surface, the separations between the two, referred to as *geoid undulations*, *geoid heights*, or *geoid separations*, will be irregular as well.

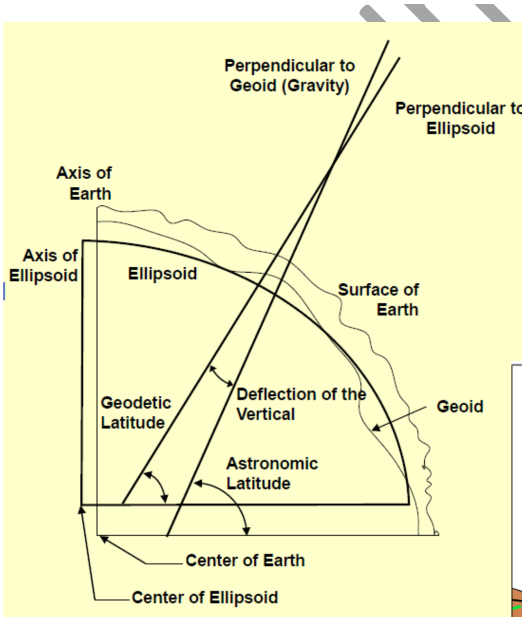
من ناحية أخرى ، يتطابق الجيؤيد مع ذلك السطح الذي تتوافق معه المحيطات على الأرض بأكملها إذا كان خاليا من التأثير المشترك لجاذبية الأرض (الجاذبية) وقوة الطرد المركزي لدوران الأرض.

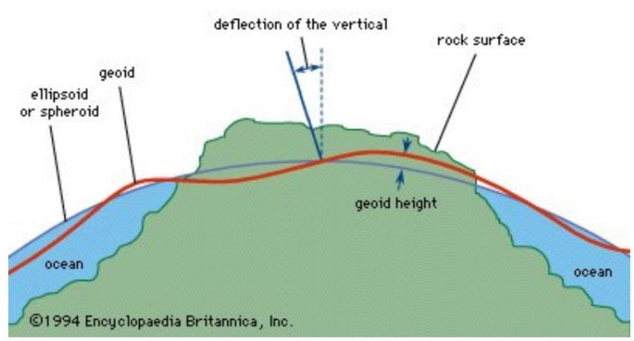
نتيجة للتوزيع غير المتكافئ لكتل الأرض ، فإن السطح الجيؤيدي غير منتظم ، وبما أن *ellipsoid* هو سطح منتظم ، فإن الفواصل بين الاثنين ، والتي يشار إليها باسم التموجات الجيؤيدية ، أو الارتفاعات الجيؤيدية، أو الفواصل الجيؤيدية، ستكون غير منتظمة كذلك.

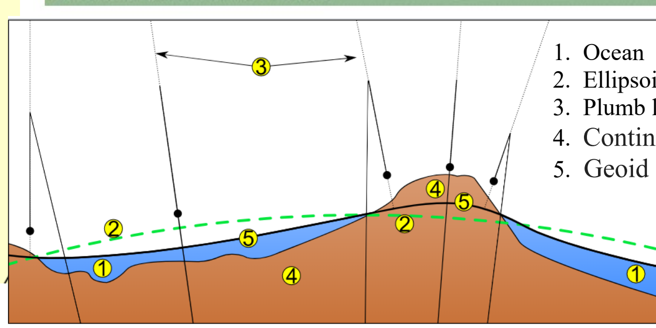
The geoid is a surface along which the gravity potential is everywhere equal and to which the direction of gravity is always perpendicular. The latter is particularly important because optical instruments (e.g. theodolite and level) containing “*gravity-reference leveling devices” (the bubble)* are commonly used to make geodetic measurements leveled. When properly adjusted, the vertical axis of the instrument coincides with the direction of gravity and is, therefore, perpendicular to the geoid.
The angle between a plumb line, which is perpendicular to the geoid (sometimes called "the vertical") and the perpendicular to the ellipsoid (sometimes called "the normal"), is defined as the *deflection of the vertical*. It has two components: an east-west and a north-south component.

الجيؤيد. عبارة عن سطح يتساوى فيه جهد الجاذبية في كل مكان ويكون اتجاه الجاذبية متعامدًا عليه دائمًا . هذا الأخير مهم بشكل خاص لأن الأدوات البصرية (كالثيودولايت واللفل) تحتوي على أجهزة تسوية الجاذبية المرجعية (الفقاعة) تستخدم عادة لجعل الاجهزة الجيوديسية متزنة. عند تعديله بشكل صحيح ، يتطابق المحور الرأسي للجهاز مع اتجاه الجاذبية ، وبالتالي ، يكون متعامدًا مع الجيود.

يتم تعريف الزاوية بين خط الشاقول المتعامد مع الجيود (يسمى أحيانًا اتجاه الجذب الارضي) والعمودي على الشكل ellipsoid (تسمى أحيانًا "العمود") على أنها انحراف العمود (*زاوية انحراف الشاقول*). تتكون الزاوية من مركبتين: افقية من الشرق إلى الغرب وعمودية من الشمال إلى الجنوب.







What is the Geoid?

The geoid is a level, or equipotential surface, where the gravity potential is a constant value. The gravity force vector acts perpendicular to this surface. A good example of a level surface would be a large body of water where the force of gravity acts on the water such that a constant surface is formed.

This is where the Mean Sea Level (MSL) height stems from. The surface of the ocean, after some generalization, can be considered as a good approximation to the geoid.

Geoids are generally formed by way of gravity measurements and intensive computations to formulate models. These models provide a reference from which heights can be measured.

ما هو الجيؤيد ؟

الجيود عبارة عن سطح مستوي أو متساوٍ الجهد حيث يكون جهد الجاذبية قيمة ثابتة. يعمل متجه قوة الجاذبية بشكل عمودي على هذا السطح. من الأمثلة الجيدة على سطح مستوٍ وجود جسم كبير من الماء حيث تعمل قوة الجاذبية على الماء بحيث يتشكل سطح ثابت.

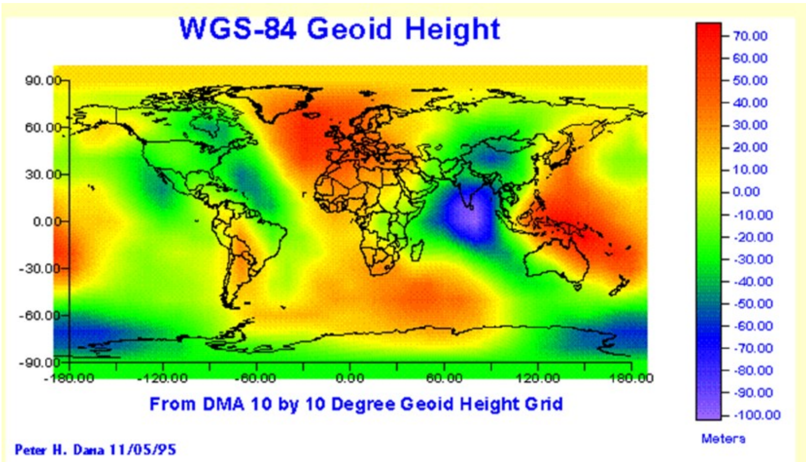
هذا هو المكان الذي ينبع منه ارتفاع متوسط مستوى سطح البحر (MSL). يمكن اعتبار سطح المحيط ، بعد بعض التعميم ، بمثابة تقريب جيد للجيؤيد.

يتم تشكيل الجيؤيد بشكل عام عن طريق قياسات الجاذبية والحسابات المكثفة لصياغة النماذج. توفر هذه النماذج مرجعًا يمكن من خلاله قياس الارتفاعات.

Geoidal Characteristics:

- Geoid is an equipotential surface of the Earth's gravity field, which approximates the mean sea level.
- The geoid is perpendicular to the direction of the gravity pull of the earth.
- Since the mass of the Earth is not uniform at all points, the magnitude of gravity varies and the shape of the geoid is hence irregular.
- The actual measurements made on the surface of the earth (topography) with certain instruments are referenced to the geoid.
- This surface has a constant gravity potential and to which the direction of gravity is always ***perpendicular***.
- As a result of the uneven distribution of the earth's mass, the geoidal surface is irregular and, since the ellipsoid is a regular surface, the two will not coincide.
- The separation in these two surfaces is referred to as ***geoid undulations***, geoid heights, or geoid separations.
- ***Physical geodesy*** utilizes measurements and characteristics of the earth's gravity field to deduce the shape of the geoid.

With sufficient information regarding the earth's gravity field, it is possible to determine geoid undulations, gravimetric deflections, and the earth's flattening. Recent gravity models and satellite based observations show that geoid rises and falls over spheroid as much as -100 m to + 100 m.



Two distinctly different types of gravity measurements are made:

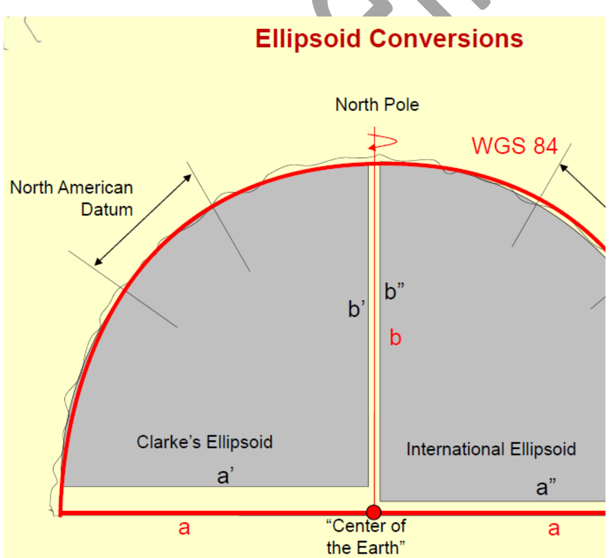
Absolute gravity: If the value of acceleration of gravity can be determined at the point of measurement directly.

Relative gravity: If only the differences in the value of the acceleration of gravity are measured between two or more points.

Comprehensive knowledge of the Earth's gravity field is a fundamental requirement for geoid determination and establishment and maintenance of modern spatial reference frames and standards in any country.

What is the Ellipsoid?

The spheroid or the *reference ellipsoid* is a smooth elliptical model of the earth that describes the true shape of the earth. Therefore, the ellipsoid is an approximation to the geoid. It can be derived mathematically and is generally referred to as a terrestrial reference frame. For example, the World Geodetic System 1984 (WGS-84) is an ellipsoid that all GPS measurements reference.



لاختيار السفرويد كسطح مرجعي في منطقة معينة:

يجب ان يكون له الخصائص التالية:

1. محوره القطبي (a) ينبغي ان يكون قدر الامكان منطبقا او موازيا لمحور دوران الارض.
2. مركزه الهندسي اقرب ما يكون الى مركز الجذب الارضي.

A *reference ellipsoid*, customarily chosen to be the same size (volume) as the geoid, is described by its semi-major axis (a: equatorial radius) and flattening f. The quantity f = a − b/a, where b is the semi-minor axis (polar radius), is a purely geometrical one.

For example, The 1980 Geodetic Reference System (GRS 80) posited a 6,378,137 m semi-major axis and f= 1:298.257 flattening. This system was adopted at the XVII General Assembly of the International Union of Geodesy and Geophysics (IUGG). It is essentially the basis for geodetic positioning by the Global Positioning System (GPS) and is thus also in widespread use outside the geodetic community. The numerous systems that countries have used to create maps and charts are becoming obsolete as countries increasingly move to global, geocentric reference systems using the GRS 80 reference ellipsoid.

يتم وصف الالبسويد المرجعي ، الذي يتم اختياره عادة ليكون بنفس حجم (حجم) الجيؤيد ، من خلال عنصرين : (a , b) او(a , f)
حيث يحسب التفلطح من خلال العلاقة (f = a - b / a) .
اذن خلاصة دراسة السطوح, فان القياس يجرى على السطح الطبوغرافي المتعرج (ارتفاعات وانخفاضات) من خلال اجهزة تعدل وتنسب الى سطح الجيؤيد (سطح تساوي الجهد) الذي يكون اكثر انتظاما من السطح الطبوغرافي لكن السفرويد سيكون اكثر انتظاما ويمكن التعامل معه رياضيا. لذلك نحتاج الى حساب المواقع الجيوديسية على هذا السطح.

2nd) Positions and Reduction quantities to the Ellipsoids

There are different kinds of positions in geodesy:

1. Astronomic positions (φ_i' , λ_i' , A_i') related to Geoid.
2. Geodetic positions (φ_i , λ_i , A_i) related to Spheroid.
3. Horizontal Control.
4. Vertical Control.
5. Gravimetric Techniques.
6. Satellite positioning.

تؤخذ الارصادات الفلكية نسبة الى الجيؤيد وتحتاج الى تحويله الى قيم حسابية (قيم جيوديسية) على سطح السفرويد.
لذلك يمكن الحصول على المواقع الجيوديسية بعدة طرق تكمل احداها الاخرى:

Point position is solved by computation from measurements linking the known positions of terrestrial or extraterrestrial points with the unknown terrestrial position. This may involve transformations between or among *astronomical* and *terrestrial* coordinate systems. The known points used for point positioning can be triangulation points of a higher-order network or GPS satellites.

Astronomical latitude (φ_i'): the angle between the plane of the earth's equator and the plumb line (direction of gravity) at a given point on the earth's surface.
The common geodetic position information can be displayed in two standard ways:

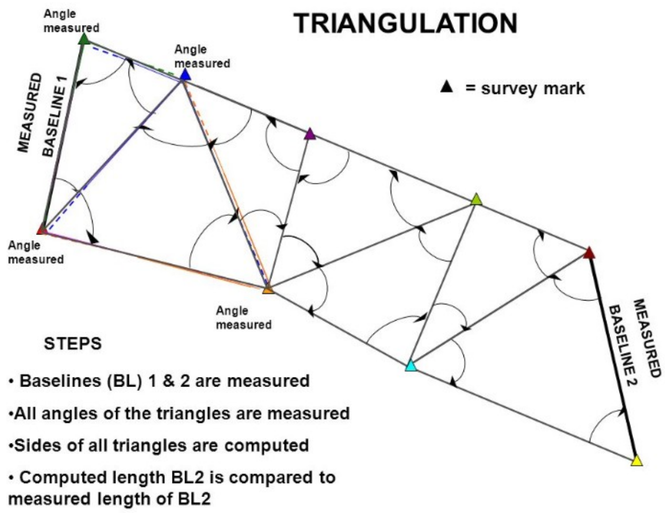
1. Curvilinear Coordinates:
   - (φ) Geodetic Latitude
   - (λ) Geodetic Longitude
   - (h) Ellipsoidal height.
2. Cartesian or Earth Centered Earth Fixed (ECEF) Coordinates
   - X: Passing through the Greenwich Meridian
   - Y: Orthogonal to the x axis (left handed)
   - Z: Perpendicular to the (X, Y) origin; passing through the pole.

When a line is measured on the surface of the earth it must be reduced to an equivalent distance on the reference ellipsoid before further computations.

Horizontal Control:

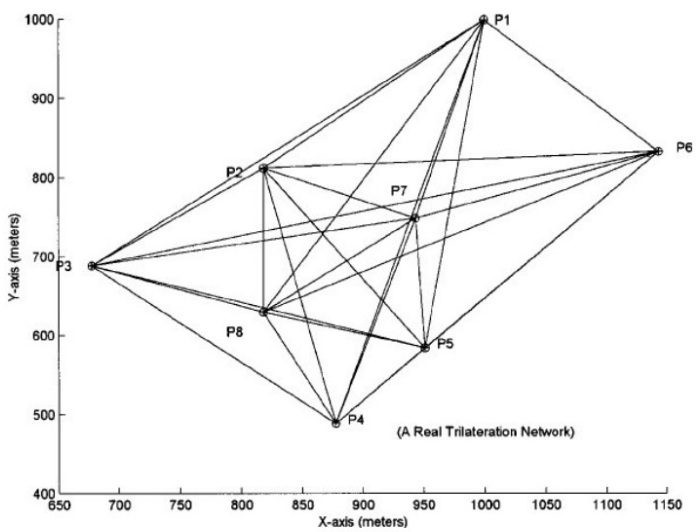
1- Triangulation:

The triangulation represent the tracing and measurement of a series or network of triangles in order to determine the distances and relative positions of points spread over an area, especially by measuring the length of one side of each triangle and deducing its angles and the length of the other two sides by observation from this baseline.



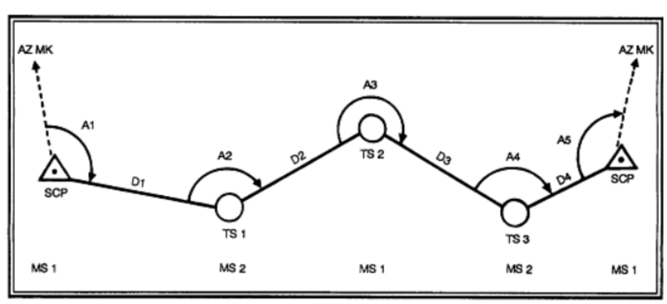
2- Trilateration:

Because of the development of highly accurate electronic measuring devices, a triangulation system can be completely observed, computed and adjusted by measuring the lengths of the sides in the network. This procedure is known as trilateration. No horizontal angle need to be measured because the lengths of the sides are sufficient to permit both the horizontal angles and the positions of the stations to be computed.



3- Traversing

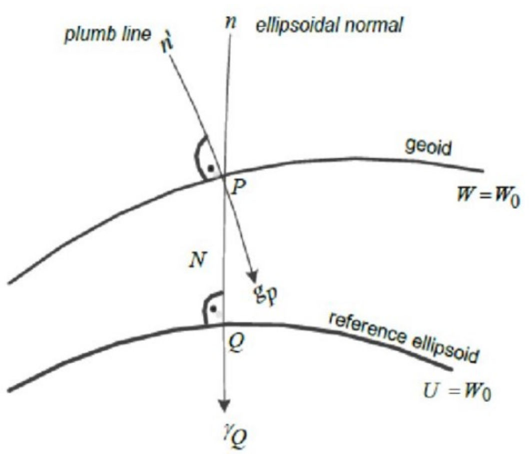
A traverse consists of a series of straight lines of known length related to one another by known angles between the lines. The points defining the ends of the traverse lines are called the traverse stations. Traverse survey is a method of establishing control points, their positions being determined by measuring the distances between the traverse stations which serve as control points and the angles subtended at the various stations by their adjacent stations.

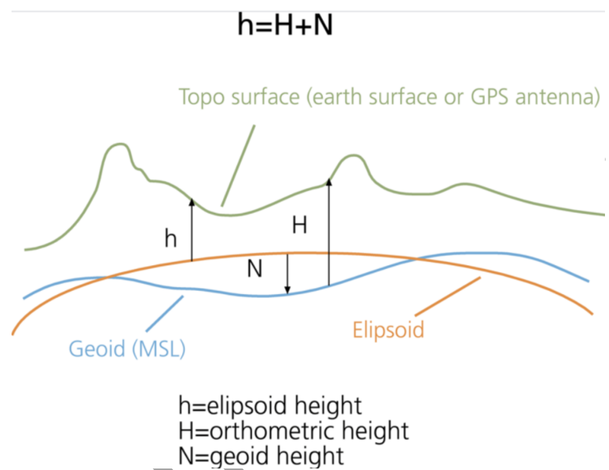


Vertical Control:

Precise geodetic leveling is used to establish a basic network of vertical control points. From these, the height of other positions in the survey can be determined by supplementary methods.

In general, vertical surveying is the process of determining elevations above mean sea-level, while geodetic positions are referred to an ellipsoid. Therefore the transformation is required.





3rd) Orientation and Coordinate Conversion between Ellipsoids

Standard *Molodensky Datum Transformation* used for converting (φ_1, λ_1 and h_1), (h_1 is the ellipsoidal elevation) on the first ellipsoid of known ('a' and 'f') to points (φ_2, λ_2 and h_2) on the second ellipsoid where (a' and f'), and the shift parameters $\partial x, \partial y, \partial z$ are known. Negative values are used for western longitudes these equations calculate $\delta\varphi$ *and* $\delta\lambda$ in radians and δh in meters.

Thus, $\delta a = a' - a$

$\delta f = f' - f$

Ellipsoid	a	1/f
Airy 1830	6377563.396	299.325
Bessel 1841	6377397.155	299.153
Clarke 1866	6378206.4	294.979
Clarke 1880	6378249.145	293.465
Everest (India 1830)	6377276.345	300.802
Helmert 1906	6378200	298.3
Hough 1960	6378270	297
International 1924	6378388	297
GRS 80	6378137	298.257
WGS 72	6378135	298.26
WGS 84	6378137	298.257

Delta parameters are with respect to WGS-84 parameters for conversion from the specified datum to WGS-84.

Geodetic Datum Transformation Parameters (Local to WGS-84)
d = delta in meters; e = error estimate in meters; #S = number of satellite measurement stations

Datum	Ellipsoid	dx	dy	dz	Region of Use	ex	ey	ez	#S
North American 1927	Clarke 1866	-7	162	188	Canada (Alberta; British Columbia)	8	8	6	25
North American 1927	Clarke 1866	-9	157	184	Canada (Manitoba; Ontario)	9	5	5	25
North American 1927	Clarke 1866	-22	160	190	Canada (Maritime Provinces; Quebec)	6	6	3	37
North American 1927	Clarke 1866	4	159	188	Canada (N.W.T.; Saskatchewan)	5	5	3	17
North American 1927	Clarke 1866	-7	139	181	Canada (Yukon)	5	8	3	8
North American 1983	GRS 80	0	0	0	Canada	2	2	2	96
North American 1927	Clarke 1866	-10	158	187	MEAN FOR Canada	15	11	6	112
North American 1983	GRS 80	0	0	0	Continental U.S.	2	2	2	216
North American 1927	Clarke 1866	-8	160	176	MEAN FOR Continental U.S.	5	5	6	405