It is interesting to notice that the decrease of the anomaly is not limited to the station of Punta Delgada on São Miguel, but that it comprehends likewise the stations Nrs. 11 and 13, although these stations are both on deep water.

I don't wish to make an attempt at explanation of these curious results before the final computations give a satisfactory base for it. They are certainly contrary to all former opinions that volcanic islands present excesses of gravity because of the heavy material of which they are built.

On Madeira an excess was found, which also extends over a greater area than the island. The provisional results of the stations Nrs. 41—46 are

Nr.	Isostatic Anomaly	
41	+ 29 milligal	
42	+ 63 „	
43	+ 81 „	
44	+ 72 „	(Madeira)
45	+ 25 „	
46	+ 34 „	

In this connection the results found in 1926 near the Canarian Islands may be mentioned. In Las Palmas, on the island of Gran Canaria, the isostatic anomaly was + 83 milligal, but near the island of Teneriffe, at sea, a value was found of + 11 milligal. The neighbouring stations gave anomalies of + 4 and + 42 milligal. With the exception of the low value near Teneriffe these results as well as those near Madeira are in harmony with the old conception of positive anomalies on volcanic islands.

Geology. — *Some additional notes on the Permo-Carboniferous Orogeny in North America.* By W. A. J. M. VAN WATERSCHOOT VAN DER GRACHT.

(Communicated at the meeting of November 26, 1932).

Professor CHARLES SCHUCHERT (Yale) has published a review in Amer. Journal of Science, July 1932, Scientific Intelligence, (pp. 88—89) of my treatise on the Permo-Carboniferous Orogeny in the South-Central United States, as appeared in the Verhandelingen (Vol. 27, No. 3, 1931). A shorter account with the same title was published in the Bulletin of the American Association of Petroleum Geologists (Vol. 15, pp. 991—1058) 1931.

SCHUCHERT rightly asks *"is this orogeny really so tremendous"?*

This is indeed the great question; we may theorize about it, but, unfortunately, we can scarcely expect a decisive answer, for a considerable time to come at least. I need not repeat here the several points of my argument, taken from features of the mountains as well as of the foreland, in constant comparison with what we know of the front of the great Permo-Carboniferous system of Europe. Here in Europe the heart of the mountains, happily, is fairly well exposed to investigation, with ever more remarkable results as to the truly tremendous dimensions of the orogeny on this side of the Atlantic. In the United States the interior chains and the hinterland are buried under the very thick blanket of the Gulf Coast Tertiary and Cretaceous, and I fear beyond hope of much further discovery in the Gulf Plain. The mother stratum of the salt domes in the Houston district, on the basis of geophysical data, must lie at a depth of at least 15000 feet, and more probably 20000 feet. The drill has only been able to tell us that at Sulphur La. the basis of the salt dome is much deeper than 9200 feet (BARTON). Consequently, our only hope to learn something about the Paleozoic basement of this area is geophysical speculation. D. C. BARTON has recently communicated a synopsis of our data on this subject at the 13th Annual Meeting of the American Geophysical Union (Report General Assembly National Research Council, Washington, April 29, 1932). It appears that the salt domes of the coastal group lie in a broad areal trough of gravity minima, which is especially sharp in Louisiana and whose axis coincides with the southern Louisiana salt dome line between Lake Charles and Crowley, and runs approximately across the Vinton-Lockport-Iowa-Welsh-Roanoke-Jennings salt domes. Unfortunately, it is by no means certain what this low gravity zone really means. Following BARTON, I may mention four alternatives:

1. It may be wholly the effect of a deposit of low density rocksalt, the mother stratum of the salt domes;

2. It may be the effect of a synclinal trough, in which a salt lens lies axially and is arched up convexly into a salt ridge, or merely the axial zone of a thick elongated salt lens;

3. It may be the combination af (*a*) a seaward increase in thickness of the sediments and the dip of the basement on which they rest, and (*b*) the regional increase of gravity in the Gulf sea basin (of still obscure origin, but probably connected with a thinning of the lighter outer crust and relative shallow depth of dense subcrustal elements). The greatest thickness of sediments does not coincide with the axis of the gravity minimum; the former lies at or off the coast;

4. In the combination may enter a western prolongation of BOWIE's area of negative isostatic anomaly, which more or less coincides with the Appalachian trough, involving a westward curvature of this trough, whilst to the south of the Louisiana—Texas negative zone would follow a pro-

longation of BOWIE's area of positive anomaly, which more or less coincides with the Appalachian Piedmont belt.

If this last interpretation of part of the anomalous effect holds true, it might be an indication of the *general* WSW trend of the Permo-Carboniferous mountains under the Gulf coastal sedimentary blanket, apart from northward lobes of the outer front of the orogeny, so particularly conspicuous in the Ouachita Mountains proper.

The only chance, and I believe a fairly good one, to find *outcrops* of the interior structure exists in Chihuahua and Sonora and in uplifts in the sierras of Coahuila. We know of an outcrop of Paleozoics at Torreon, on the border of the state of Durango (Permian), and even as far to the southeast as near Victoria in Tamaulipas (Mississippian and Permo-Carboniferous). Unfortunately outcrops will probably be confined to small uplifts in the Tertiary folds, but yet they may give valuable evidence if we hit as lucky a spot as at Marathon or Solitario.

For the present, therefore, our data as to the interior zones of the greater Ouachita complex are extremely meager. If, however, it is truly a major world-orogeny, and, as I conceive it, encircling the southern rim of the Paleozoic continental mass of North America, and not a more or less local affair, it should be possible to find some traces of *the continuation of these chains farther west.* Here, unfortunately, we again enter very little worked territory, particularly in northwestern Mexico, and moreover the Paleozoic picture becomes very much obscured by the great sequence of Mesozoic and Tertiary revolutions which affect the Pacific side of the continent, and are almost continuous from Jurassic time to the present period. The Andine (late Jurassic) orogeny in particular has profoundly changed the sediments by regional metamorphism, aggravated by tremendous intrusions of batholiths.

Last winter, when I had an opportunity to revisit the United States, I gave some attention to possible indications of the late-Paleozoic orogeny west of the Cordilleran front and discussed the problem with such geologists as N. H. DARTON, D. F. HEWETT, R. T. HILL, P. B. KING and W. S. BURBANK, who kindly gave me the benefit of their extensive knowledge of these but imperfectly explored vast regions.

The foreland chain of the Wichita-Amarillo Mountains does not stop dead at the front of the Sangre de Christo range, but, evidently, the WNW-trend continues farther to the northwest and is traceable as far as western Utah. Even as far to the northwest as the Columbia Plateau of Oregon, E-W ridges of Paleozoics emerge, crossed by the N-S Tertiary trends (E. L. PACKARD, Am. Journ. of Science, Vol. 15, 1928, p. 221). All these, however, are remodelled by Tertiary orogeny.

The general region of Arizona, New Mexico, Colorado and Utah is

dominated by a great positive mass, active through all geologic history. This Colorado Plateau is composed of two separate major elements: the Front Range block and the Uncompahgre Massif. They are separated by a marked zone of weakness, into which the Tertiary folds of the Sangre de Cristo system swing conspicuously. These folds at first constitute the west front of the Colorado Massif in northern New Mexico and southern Colorado, and then, just south of the Arkansas River canyon, swing to the northwest in between the two blocks. These folds, revived by Tertiary diastrophism, continue in the Uintah Mountains, are crossfolded by the N—S Wasatch Range, but reappear beyond the Salt Lake Valley of Utah and are traceable in the same E—W trend as far as the Nevada border. A system of minor warpings of WNW trend traverses the entire region. It may be very difficult to work out the Paleozoic structure underlying the Laramide and the late-Tertiary orogenies. The uplift has been so considerable that Pennsylvanian and often Permian directly repose on the pre-Cambrian; the later-Tertiary uplifts have added large areas of exposed pre-Cambrian floor, having caused the erosion of the entire remaining blanket of Paleozoic sediments. The enormous conglomerates in the Pennsylvanian, however, are ample proof of the importance of late-Paleozoic orogeny; the Permian rests unconformably on different Pennsylvanian horizons and becomes increasingly clastic towards the pre-Permian landmasses. The Arbuckle phase of the latest Pennsylvanian is conspicuously indicated, notably for the Sangre de Cristo system, but other locations in the Colorado Massif and the Front Range block give evidence of the earlier-Pennsylvanian Wichita phase.

The Wasatch Range shows strong overthrusting towards the east in Tertiary time, (but also Mesozoic diastrophism): it constitutes the eastern edge of the great Cordilleran Paleozoic geosyncline. Already in the Uintah Mountains the Paleozoics are largely in limestone facies. The swing of the folds would seem to indicate a NE-ward lateral displacement of the entire Colorado (Uncompahgre) Massif, not participated in by the Front Range block, at least not much after the Wichita phase in the early Pennsylvanian.

All the above described orogeny, however, is movement of a foreland type, similar to the orogeny in the Wichita and Amarillo Mountains and very distinct from the Ouachita type of mountain structure.

Along the southern and southwestern side of the Colorado Massif in Arizona and southern New Mexico another system of post-Laramide, late-Tertiary folds, partly overthrust, of the Sierra Madre system (after R. T. HILL) indicate a renewed push from the southwest, which, this time, did not again displace the Colorado buttress. These folds continue from southern Nevada to Tamaulipas. This orogeny is of Pliocene age in its major phases.

The main (outer) Ouachita system.

To the southwest the Paleozoic chains of the Ouachita system of the

Marathon Mountains are lost under the Sierra Madre folds of the Mount Ord and Santiago ranges; they once more crop out in the small isolated dome of the Solitario. In both these erosional windows they are most vigorous (nappe-overthrusts) and the facies of the older Paleozoics remains of the same geosynclinal type.

What becomes of the Paleozoic mountains farther west?

At first they are lost under the practically unknown Tertiary mountain folds of Chihuahua and Sonora, but here more erosional windows may be expected on the uplifts.

In the southwestern desert province of Arizona, the Altar district of northwestern Sonora, the Mohave desert, and the cross ranges of southern California, *we again find indications of a Paleozoic geosyncline, which may exist not far distant to the south.* This syncline is not identical with the old-Paleozoic Cordilleran geosyncline. In Nevada the Paleozoics do not yet belong to the Cordilleran geosynclinal province proper, but they already begin to thicken rapidly toward the west, a process apparently accelerated by the great crustal shortening in this region; they thicken from 400 to 12000 feet in this area, mostly in the Cambrian section. The sedimentation seems interrupted in the Silurian.

However, the highly metamorphosed sediments of southwestern Arizona, to the southwest of the northern mountain region of the state, are again more shaly than the limestone facies of the Plateau. The rocks are now marbles, interstratified with shists, some quartzites, and pierced by monzonite-granite intrusives. Spare fossils indicate Pennsylvanian and Permian (Kaibab fauna) in this sequence. Marine Trias is reported from the Altar district in Sonora. Thick Paleozoic sections have also been reported from Sonora, but no study has yet been made of the area. In the Mohave desert ranges of California we also find highly metamorphosed Paleozoics. J. B. TENNEY believes the orogeny to be lower Triassic.

In Arizona the younger formations seem to overlap progressively on the southwestern pre-Cambrian edge of the Colorado Plateau. Strong plication is post-Kaibab. The conglomerates in the Triassic Shinarump and Chinle formations are derived from a southern source and indicate elevated (and wooded) highlands in that direction, subject to erosion in early Triassic time. The metamorphism and plication, however, must be accepted with caution, because the only visible outcrops are in island mountains piercing the recent desert filling. It is just possible that both are caused by and restricted to monzonite intrusions, and that now only these hardened areas stand out of the relief.

In the Mountain Region of northern Arizona conditions are strikingly different: there is no pre-Tertiary folding and no evidence of geosynclinal conditions. We are well on the interior Plateau. The widespread Paleozoic sediments are irregularly deposited, in Plateau facies, and not metamorphosed. In the Catalina Mountains, at Roosevelt Lake, Globe, Ray, the pre-Cambrian is covered by upper-Devonian, Mississippian and Penn-

sylvanian. In the southeastern corner of Arizona, at Bisbee, these aggregate 5000 feet. In the Chiricahua Mountains on the border of New Mexico the section includes Permian. Unconformities are in evidence at the base of the Monkoepi (Trias) and at the base of the Pennsylvanian.

All this suggests that in southwestern Arizona we might be again near the edge of the Paleozoic continent of North America against the marginal geosyncline, and on the front of an arcuate chain of folded and metamorphosed Paleozoics in geosynclinal facies. If this is true, this southern metamorphosed zone might well be a western prolongation of the Ouachita geosyncline of Marathon, now turning west and northwest along the southwestern rim of the continental mass, possibly forming another plateau-ward lobe, with its apex in southwestern Arizona and southern California. We may find evidence in the sedimentation of an outer Pennsylvanian-Permian foredeep belt, affected by a very late-Paleozoic, perhaps early Triassic diastrophism (cf. Bissett phase of the Glass Mountains at Marathon). The Paleozoic trends are of course crossfolded and deformed by the Tertiary Pacific trends. In southern California, particularly, the Ventura-Santa Barbara cross ranges (largely controlled by faults) are highly suggestive of the older E—W trend. A continuation of this feature is even indicated in the regional relief of the bottom of the Pacific Ocean, far out from the coast and continuing beyond the inner shelf. This suggests that we witness a *major* accident in the earth's crust.

In Nevada and southeastern California there is vigorous later thrusting to the east and northeast, in two cycles: Laramide (Paleocene) and post-Miocene. Some of the Laramide thrusts represent real nappes with many outliers. They are arcuate to the northeast, very complicated and connected with normal faults of great throw and general N—S to NW trend. The thrustzone extends all along the southeastern state line of California. The Paleozoics are thrust on Kaibab and Monkoepi; they are *non-metamorphic* and comprise Cambrian, Devonian, Mississippian and Pennsylvanian; pre-Cambrian is also involved. In eastern San Bernardino county the thrusts become lost against the great intrusive batholith of early-Tertiary monzonite. In the Providence Mountains the Paleozoics are still non-metamorphic: we must still be north of the metamorphosed zone. In the western portion of this area the Trias is non-red, in Pacific facies, very distinct from the red facies of the Monkoepi of Arizona and most of Nevada (D. F. HEWETT). Very little is known of the Paleozoics in the transverse ranges of southern California. The very few known fossils are Carboniferous. The shists may be in part Paleozoic (DARTON).

In the Sierra Nevada unit the highly metamorphic Paleozoic Calaveras formation is considered Carboniferous. From the very thick slates of the Blue Canyon formation Mississippian fossils are reported. Indications exist that the major Jurassic revolution is preceded by an earlier metamorphism and by two Paleozoic phases, at the top and again lower down in the Calaveras sequence (cf. FERGUSON & GANNETT, U.S. Geol. Survey Prof.

Paper N°. 172, 1932). These may represent the Arbuckle and Wichita phases.

The above very brief analysis of conditions found in the extreme Southwest does not *prove* anything sofar, but nevertheless contains some suggestive elements: there are indications of late-Paleozoic diastrophism, of E—W old trends, and of a metamorphosed zone of geosynclinal deposition to the south and southwest of plateau conditions in Arizona and Nevada. Everything is much obscured by the strong Jurassic, Paleocene and Tertiary orogenies of the Pacific province and much further study, here and in Mexico, will be needed before any more definite conclusions may be drawn. Progress with similarly difficult work in the eastern Alps of Austria has proven that it is possible to unravel such older events, even in the midst of most intense later orogenies. If my guess is right, that we may consider the area in the Southwest as the westermost prolongation of the Ouachita zone, this would support my conception that this orogeny is in reality "tremendous", and may be considered on a par with the enormous bundles of late-Paleozoic folds which, east of the Atlantic, are such an important element of the sceleton of the present continent of Eurasia, to the south of the older-Paleozoic and Archaic-Proterozoic nuclei. As the Alpine orogeny is recognized to encircle the globe in both hemispheres, the Permo-Carboniferous orogeny would do the same. This is to be expected, since here in Europe there is much evidence that the late-Paleozoic orogeny was certainly not less important than the Tertiary Alpine revolution, probably more so. Where these former enormously wide and complex chains are known to encompass half the world, it would be curious if in the western hemisphere they should be confined to a few smaller orogenies of only local significance.

Geology. — *Remarks on the undation-theory of* VAN BEMMELEN. By PH. H. KUENEN. (Communicated by Prof. L. RUTTEN.)

(Communicated at the meeting of November 26, 1932).

In a series of publications VAN BEMMELEN has suggested a number of important alterations in the oscillation-theory of HAARMANN. Excellent illustrations help to render his opinion clear. A brief summary of the undation-theory is as follows.

Crystallisation in the undifferentiated salsima is the cause of differentiation in a lighter sal floating on a heavier sima. These parts are in isostatic equilibrium with the undifferentiated salsima round about them, but not in hydrostatic equilibrium. The salsima shows a greater hydrostatic pressure except at the surface and at the base. Therefore it will be pressed in