lutely pure, natural races. Wherever nature is experimenting, as discerned by the field zoologist in the observation of geographic series from east to west, and north to south, from humid into arid regions, we are repeatedly finding geographically continuous series which shade into each other in color, in skull proportion, and limb proportion, and all other characters by continuous degrees of change.

Henry Fairfield Osborn

UNDERGROUND TEMPERATURES

It is an established fact that as the earth is penetrated below the limit of seasonal changes the temperature is invariably found to rise. Observations made in deep borings, wells, tunnels and mines have been sufficiently numerous over the earth's surface to indicate that the rise of temperature with depth "can not be explained on mere local causes." The rate of temperature increase is not uniform but is found to be quite variable, not only in different localities, but frequently in the same boring. This variation of heat increment is doubtless due to a number of causes,[1] such as differences in the thermal conductivity of rocks which vary in lithologic character, structure and contained water; inequalities of topography; circulation of water; chemical action; compression, etc. Whether the heat increment observed in the superficial zone continues to the center of the earth is not known, as observations are limited to only a little more than 1/4,000 of the earth's radius. Some investigators regard it as more probable that the rise of temperature diminishes below the superficial zone.

The conducting power of rocks was first accurately measured by Forbes,[2] and later by others. Forbes found that trap rock was the poorest conductor and solid sandstone the best. Sir Archibald Geikie[3] says, "the lighter and more porous rocks offer the greatest resistance to the passage of heat, while the more dense and crystalline offer the least resistance." The British Association Committee on Thermal Conductivities of Rocks[4] expressed the resistance of quartz by the number 114, basalt by 273, and cannel coal by 1,538. The same authority[5] records that heat travels four times as fast in foliated rocks, such as slate and schist, in the direction of cleavage than across it. It has been shown also that thermal resistance is lowered by the presence of interstitial water.

The subject of underground temperature attracted attention as early as nearly two centuries ago, when observations were made in the mines of Alsace by Gensanne in 1740, who found an increase of 1° F. in 50 feet. Among some of the earlier observers may be mentioned Saussure, Humboldt, Daubuisson, de Tebra, Forbes and Fox, Henwood, Cordier, De la Rive and Marcet, Phillips and others.

From 1868 onwards the British Association Reports contain valuable contributions by the committee on underground temperatures, and a summary is published in the volume for the year 1882. In 1886 Professor Prestwich's[6] valuable contribution on the subject of underground temperatures appeared, in which he collated all available data up to that time. This paper was later revised and published in his "Collected Papers on some Controverted Questions of Geology," 1895, pp. 166–279. Observations have been made and data bearing on this subject have been contributed at intervals to the literature from 1886 to the present time, with the conclusion that while there is an undoubted increase in temperature downward, the rate is more variable than was at first supposed.

Professor Prestwich gave the number of different localities and mines where observations were recorded as 248, and the number of stations 530. He found, with but few excep-

[1] Chamberlin and Salisbury, "Geology," Vol. I., 1904, pp. 544–547; Geikie, A., "Text-book of Geology," Vol. I., 4th ed., 1903, pp. 63–64.

[2] *Trans. Roy. Soc. of Edinburgh,* Vol. XVI., p. 211.

[3] "Text-book of Geology," 4th ed., 1903, Vol. I., p. 63.

[4] Rept. Brit. Asso. Adv. of Science, 1875, p. 59.

[5] *Ibid.,* p. 61.

[6] *Proc. Roy. Soc. of London,* 1886, Vol. XLI., pp. 1–116.

tions, that the earlier observations were inferior and of little value for purposes of accuracy, due chiefly, he says, to the imperfection of instruments and methods of experimentation. Because of the careful digest by Professor Prestwich of the voluminous data bearing on this subject, I regard it of sufficient interest to note briefly the following extracts from this valuable paper. The author classified the recorded results on underground temperatures into—(1) metallic mines, (2) coal mines, (3) wells and wet borings and (4) tunnels. The increase of temperature was found to be: (1) metallic mines, from 1° F. in 47 feet to 1° F. in 126 feet; (2) coal mines, from 1° F. in 45 feet to 1° F. in 79 feet; (3) wells and borings, from 1° F. in 41 feet to 1° F. in 130 feet; (4) tunnels—Mont Cenis, 1° F. for 79 feet; St. Gothard, 1° F. for 84 feet. The mean of these results gave 1° F. in 64 feet. Subsequent corrected readings in the two tunnels reduced the mean to 1° F. in 60 feet.

Professor Prestwich regarded the differences in results obtained in mines, wells, etc., indicated by an examination of the tables, to be attributed to the fact that the geological conditions were unlike, and the disturbing causes of a different order. The main disturbing causes in the different groups of openings made are stated and discussed. In coal mines they are stated as (1) loss of heat through exposed surfaces, (2) effects of ventilation, (3) other causes, such as crushing of rock, escape of gas, and effects of irregularities of surface (pp. 9–21). There are local variations according to structure, percolation of water, etc. From the reliable cases, the mean increase for coal mines was found to be 1° F. in 50 feet.

In metalliferous mines the main causes affecting thermal conditions are given as (1) ventilation, (2) percolation of water, (3) hot springs, due (*a*) to chemical decomposition and (*b*) to water coming from great depths[7] (pp. 25–34). The mean thermometric gradient was found to be 1° F. in 44 feet in rock, and 1° F. in 42.4 feet in springs, with an average for the two of 1° F. in 43.2 feet.

In wells and borings the main disturbing causes are regarded as (1) pressure on the instruments, and (2) convection currents. The mean thermometric gradient in this group of openings was found to be for non-flowing wells 1° F. in 51.2[8] feet, in flowing wells 1° F. in 49.1[8] feet, with an average for the two of 1° F. in 50[8] feet.

A paper entitled "Rock Temperatures on the Rand and Elsewhere," by E. M. Weston,[9] published in a recent number of the *South African Mining Journal* is of interest. The tables which follow below are taken from this paper.

Rock Temperatures in Depth on Witwatersrand Mines

Rock Temperature at	
1,000 feet	68.75° F.
2,000 feet	73.53
3,000 feet	78.35
4,000 feet	83.15
5,000 feet	87.95
6,000 feet	92.75
7,000 feet	97.55
8,000 feet	102.35

General rate of increase, 1° F. for 250 feet.

In the Lake Superior copper district, the Tamarack shaft is reported to have reached a depth of 6,070 feet, and the Red Jacket shaft a depth of 5,315 feet. The rate of increase in temperature is given as 1° F. for 209 feet. In a note published by Professor Alexander Agassiz in 1895, the greatest depth reached in the Calumet shaft was 4,712 feet, which showed an average increase in temperature of 1° F. for 223.7 feet.[10] Two bore holes are reported put down in Silesia to depths of 6,500

[7] In his revised paper, Professor Prestwich adds "the working operations" to the list of causes affecting thermal conditions in metalliferous mines. "Collected Papers on some Controverted Questions of Geology," 1895, p. 179.

[8] 52.2, 50.6 and 51.4 feet, respectively, in the revised paper. *Ibid.*, 1895, pp. 228 and 231.

[9] *South African Mining Journal*, November 12, 1910, p. 417.

[10] "On Underground Temperatures at Great Depths," *Am. Jour. Sci.*, 1895, Vol. L., pp. 503–504.

feet and 7,347 feet, with bottom temperatures of 158° F. and 181° F., respectively.

Rock Temperatures in Brazil Mines

(St. John Rel Rey Mine, Minas Geraes)

Rock Temperature at	
324 feet	70.0° F.
624 feet	71.0
924 feet	74.0
2,073 feet	78.0
2,824 feet	84.5[11]
3,724 feet	88.0
4,024 feet	95.0

Vertical depths of more than 4,500 feet are reported reached at Bendigo, Victoria, Australia, with a rock temperature of 110° F. at 4,000 feet. At the Adalbert mine in Bohemia the greatest depth is stated to be 3,600 feet, with a rock temperature between 3,500 and 3,600 feet of 113° F.

Rock Temperatures in Kalgoorlie Mines

Rock Temperature at	
1,400 feet	84° F.
1,700 feet	83
2,000 feet	83
2,300 feet	84

Data bearing on artesian-well temperatures in the Dakotas were tabulated and discussed by Darton[12] in 1898, which indicated very high and variable temperatures and for which no satisfactory explanation was offered. Records from 42 localities were given in which the depth of well varied from 432 feet to 2,500 feet, and the rate of temperature increase ranged from 1° F. in 17.5 feet to 1° F. in 45 feet, with an average of 1° F. in 35.4 feet. At the Pittsburgh meeting of the Geological Society of America, December, 1910, Mr. Darton read a paper entitled "A List of Underground Temperatures in the United States" in which he said: "The rate of temperature increase has been found to be very variable, but in places there is a marked relation to geologic features."[13]

[11] Equals sea level.

[12] Darton, N. H., "Geothermal Data from Deep Artesian Wells in the Dakotas," *Am. Jour. Sci.*, 1898, Vol. V. (N. S.), pp. 161–168.

The records of the Committee on Underground Temperatures, of the British Association for the Advancement of Science, show a range of 1° F. in less than 20 feet to 1° F. in 130 feet, with an average of 1° F. in 64 feet. Professor Prestwich concluded that the average increase in temperature was 1° F. in 47.5 feet (p. 55). Lord Kelvin assumed the rate of increase to be 1° F. in 51 feet. A lower rate of increase is indicated in more recent deep borings that have been carefully measured. From the data given above, quoted from the article by Weston on increase of temperature with depth in metalliferous mines, the general rate of increase in thermometric gradient for the different localities is: in the Witwatersrand mines from 1,000 feet to 8,000 feet, 1° F. for each 250 feet in depth; in the copper mines of the Lake Superior district, 1° F. for each 209 feet; in the St. John Rel Rey mine, Brazil, 1° F. for each 156 feet, approximately; and in the Kalgoorlie mines, Australia, practically no variation in temperature is indicated between the depths of 1,400 feet and 2,300 feet.

Professors Chamberlin and Salisbury give the following list of records:[14]

Locality	Depth in feet	Rise of 1°F.
Sperenberg bore (Germany)	3,492	in 51.5 feet
Schladeback bore (Germany)	5,630	67.1
Cremorne bore (N. S. Wales)	2,929	80
Paruschowitz bore (Upper Silesia)	6,408	62.2
Wheeling well (W. Va.)	4,462	74.1
St. Gothard tunnel (Italy-Switzerland)	5,578	82
Mt. Cenis tunnel (France-Italy)	5,280	79
Tamarack mine (N. Mich.)	4,450	100
Calumet and Hecla mine (N. Mich.)	4,939	103
Ditto, between 3,324 feet and	4,837	93.4

In commenting on these records the authors say:

[13] "Preliminary List of Papers, 23d Winter Meeting, Geol. Soc. America, Pittsburgh, Pa.," December, 1910, p. 2.

[14] "Geology," Vol. I., Geologic Processes and their Results, 1904, p. 543.

It is to be noted that even these selected records vary a hundred per cent. Very notable variations are found in the same mine or well, and often much difference is found in adjacent records, especially those of artesian wells. Some of these are explainable, but the full meaning of other variations is yet to be found.[15]

In conclusion, it may be stated that from recent figures bearing on this subject, no general law is observed in the increase of rock temperature with depth, and in general the increment of heat is lower and more variable than indicated by the earlier observers.

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THE SCALES OF THE DIPNOAN FISHES

I AM greatly indebted to Dr. G. A. Boulenger for scales of the few living members of the very interesting and remarkable subclass known as Dipnoi or Dipneusti. The result of their examination is quite surprising to me, and has, I think, an important bearing on their relationship with other fishes.

Neoceratodus forsteri, from Queensland, has very large oblong scales, one before me being 55 mm. long and 34 mm. broad, 20 mm. or less of the length being exposed in the living fish. In general appearance, the scales are not unlike those of *Heterotis,* except for size. The broad nuclear field, far apicad of the middle, is rugose; the circuli (fibrillæ) are all very fine, and both basal and apical are longitudinal; the basal fibrillæ are moniliform (minutely tuberculate), and in the lateral fields the whole surface is minutely rather irregularly tuberculate. Thus in its longitudinal fibrillæ *Neoceratodus* agrees with *Amia* and *Albula;* in having the fibrillæ tuberculate or beaded it agrees with *Albula* and the Osteoglossidæ. At first sight it seems that there are no radii in *Neoceratodus,* but closer inspection shows a complete system of fine radial reticulations, especially well developed in the lateral areas, where it accords perfectly with the network pattern of the Osteoglossids! This exceedingly characteristic feature is now known, therefore, in the Dipnoans, the Osteoglossids and the Mormyrids.[1]

Having determined these facts, I turned with eagerness to the material of *Lepidosiren* and *Protopterus.* In these fishes the scales are completely enclosed in the skin, but are, nevertheless, quite large (fully 8 mm. diameter in *Protopterus*), and shaped much as in *Osteoglossum.* Both have a strong radial network, while the circuli are reduced to innumerable fine tubercles or coarse granulations, approaching the condition of the lateral areas in *Neoceratodus. Protopterus annectens* from Africa (Gambia) and *Lepidosiren paradoxa* from Brazil have scales of entirely the same type, but in the *Protopterus* the network is more regular and more obviously similar to that of the Osteoglossids. In both the fibrillar granulations tend to run in lines near the margin, but this is rather more marked in *Lepidosiren;* the indications are in each case of longitudinal (not circular) fibrillæ. The general results may be thrown in the form of a table, thus:

(*A*) Basal fibrillæ longitudinal.
- (*a*) Fibrillæ moniliform or tuberculate.
  - (1) With radial network ... Dipneusti.
  - (2) Without radial network. *Albula* and *Dixonina.*
- (*b*) Fibrillæ not tuberculate; no radial network .... *Amia calva, A. scutata.*

(*B*) Basal fibrillæ circular (normal circuli); radial network present.
- (*a*) Fibrillæ tuberculate ..... Osteoglossidæ.
- (*b*) Fibrillæ not tuberculate ... Mormyridæ.

It is also to be remarked that *Gymnarchus* (Mormyridæ), *Heterotis* (Osteoglossidæ), *Lepidosiren* and *Protopterus* all have larvæ with external gills.

Dr. Boulenger has very kindly sent me the scales of the Osteoglossids *Scleropages formosus* from Borneo, *Scleropages leichardti* from Queensland and *Osteoglossum bicirrosum* from Cadajos, Brazil. They are practically circular (*S. leichardti* rather broader), and all have exactly the same structure, notwithstanding the wide geographical separation. The scales of *Heterotis niloticus* differ

[15] *Op. cit.*, pp. 543–544.

[1] For the last, see Smiths. Misc. Coll., Vol. 56, No. 3, p. 2.