est in it is increasing, however, may be judged from the number of American students who have been and still are pursuing it at various German universities. What is needed in this country are well-equipped petrographical laboratories, so that those who are unable to avail themselves of the facilities which Europe affords may not be compelled to remain in ignorance of what is daily becoming a more and more necessary part of a geologist's training. An attempt to organize such a laboratory has recently been made at the Johns Hopkins university and the encouragement which it has already received seems to abundantly justify the experiment.

Heretofore microscopical petrography has been essentially a branch of mineralogy, but its future certainly lies in the far wider sphere of geology. The mere laboratory study of isolated rock-specimens, which has served so good a purpose in the perfecting of delicate and accurate methods, no longer possesses any significance, now that these are so thoroughly developed. What in Germany has been secured by years of patient labor may now be learned in a comparatively short time. Geologists have only to know and realize its application to their field of work, in order to eagerly avail themselves of such an important aid. The use of the microscope alone will in future produce but little that is new; but its possibilities in geology, when intelligently employed in connection with the most detailed and careful field-work, — the necessity of which has been increased, not diminished, by its introduction, — cannot be easily overrated.

What paleontology has done for the fossiliferous deposits, this, and even more, the microscope must do for the crystalline rocks. The less altered forms of igneous masses have thus far been almost exclusively studied; and, although they still have much to teach us, it is not by their investigation that the microscope is destined to yield its greatest assistance to geology. The changes, structural and chemical, which go on in rocks after they are first formed, leave behind them more or less distinct traces which it is the special province of the microscope to follow out and interpret. Of how much has already been learned regarding the alteration of sedimentary rocks near their contact with eruptive masses, the work of Rosenbusch in the Vosges Mountains, of Lossen in the Hartz, and of Hawes in New Hampshire, is abundant proof. The wide-spread changes which rocks subjected to regional metamorphism have undergone, are far more complicated and difficult, but they can undoubtedly be studied with as great success. It is by dealing with such problems as Lossen, Renard, and Lehmann, in Europe, and Wadsworth in this country, have especially pointed out, that the microscope in geology can in future render its best service. The manner in which this can be accomplished is by the patient following, step by step, of unchanged rocks into their most completely altered equivalents, and carefully comparing the condition of each constituent at every point. In this manner the succession of changes which they undergo may be as completely worked out as though we could see the process actually going on before our eyes. The alterations of olivine and enstatite to serpentine, of pyroxene to hornblende, and even the reaction of two minerals upon each other in forming a third of intermediate composition, as shown in the rim of amphibole which surrounds olivine where it is in contact with plagioclase, have all been traced by the microscope through every stage. More recently the effects of pressure exhibited by the bending and breaking of crystals, the disturbing of their optical characters, and the local crushing of the rock constituents, have been carefully studied. This is found almost always to be attended by the formation of new minerals, like albite, zoisite, mica, garnet, etc., whose younger origin is only to be proved by a microscopic investigation. It is impossible to mention here a tithe of what has already been done in this direction, although a beginning has hardly yet been made. What are especially to be desired are detailed studies of many small areas, where the same rock, whether eruptive or sedimentary, can be traced from its original form to its most altered state, and a comparison of the results obtained in each. This Lossen[1] has recently attempted for the southern Hartz, and has thereby indicated what is perhaps the most promising field for microscopic work in geology.

GEORGE H. WILLIAMS.

THE SPANISH EARTHQUAKES.[2]

THE Spanish peninsula has been the scene of a series of earthquakes, which, for extended duration and disastrous effects, surpasses any thing that has been felt in that region in recent

[1] Studien an metamorphischen eruptiv- und sedimentgesteinen, erläutert an mikroskopischen bildern. Jahrbuch der preuss. landesanstalt für 1883, p. 619.

[2] In preparing this notice, the following journals have been consulted; viz., Cronica cientifica (Barcelona), Science et nature, La Nature, L'Astronomie, Comptes rendus, Cosmos, Hansa, Nature, and various English and American newspapers.

years. Beginning toward the close of December last, the shocks continued at intervals for more than a month, and, indeed, the ground has hardly yet resumed its wonted stability; while the loss of life and destruction of property, exceeding that of 1829 in Valencia, has perhaps not been equalled since the great Lisbon earthquake of a century ago.

The first light shocks were reported in the early morning of Dec. 22, 1884, at Pontevedra and Vigo on the north-west coast, and were also felt at Lisbon and other places in Portugal, on the island of Madeira and the Azores.

This was followed on the evening of Dec. 25 by disastrous shocks in the southern part of the peninsula. They began at 8.53 P.M., being felt as far north as Madrid, where bells were rung and clocks stopped, but doing no damage there; while in the southern provinces of Andalusia, Granada, and Malaga, where the principal force was expended, hundreds of houses were overthrown, hundreds of lives lost, and some towns and villages entirely destroyed.

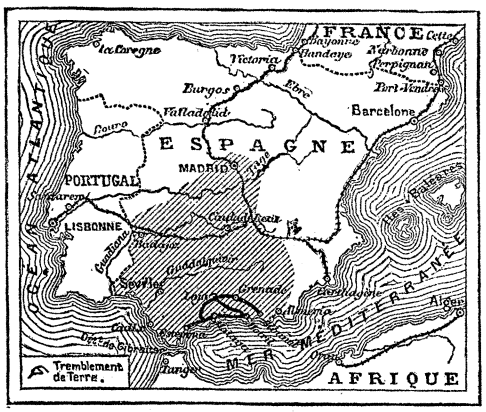
VIEW IN A STREET OF ALHAMA, JAN. 3. (From *La Nature.*)

In Cadiz, Seville, Cordova, Jaen, and Almeria the shocks were strongly felt, injuring some buildings, but without serious damage. At Granada, shocks to the number of eight occurred during that night; and, besides other casualties, the front of the cathedral was injured, the Alhambra fortunately escaping harm. The villages of Albuñuelas, Arenas del Rey, Jatar, Zafarraya, and Santa Cruz, were left a mass of ruins. Alhama was destroyed with the loss of over a thousand houses and three hundred and fifty lives. This town consisted of two parts, — an upper and a lower. The upper portion, situated upon the higher ground, was cast down upon the lower, overwhelming it in its fall. The hot springs also ceased to flow for two days, after which, the flow was resumed more abundantly than before. The waters have since then acquired a marked sulphurous character, and their temperature has increased from 47° C. to 50° C.

The province of Malaga also suffered severely. In the city of Malaga all the public buildings were injured, and some were destroyed with many other houses. At Estepona, on the coast west of Malaga, a church and a block of buildings were destroyed. At Torrox, Nerja, Almuñecar, and Motril, places on the Mediterranean Sea east of Malaga, many buildings were overthrown, and many lives lost. In the first-mentioned place, as stated by the alcalde, twenty-six shocks occurred between 8.50 P.M. of the 25th and 11 A.M. of the 26th, completely destroying the village. At Almuñecar twelve shocks occurred in fifteen minutes. At many places where the destruction was less complete, especially at Granada and Malaga, the inhabitants camped for days in the fields and open places, sleeping in tents and sheds, or in carriages, not daring to return to their houses. At Periana, north of Malaga, an extensive land-slip was caused by the earthquake, overwhelming a large part of the town, and destroying a church and seven hundred and fifty houses. Above the village of Guevejar, built upon a hillside, a great parabolic crevasse three kilometres long has opened to a width of from three to fifteen metres; and the village, which rests on a stratum of clay, is slowly sliding downward to the valley, while the houses still remain standing. Some of the houses have moved twenty-seven metres since Dec. 25.

At one extremity of the crevasse a small lake has been formed, having a depth of nine metres, and a superficial area of about two thousand square metres. At another point an olive-tree has been split from root to branches, the two parts remaining upright upon opposite sides of the opening. At still another point, it has divided lengthwise the foundation-wall of a powder-manufactory.

As many of the villages in that part of Spain do not have telegraphic communication with the capital, details have been reported slowly and with considerable uncertainty; and it is difficult to gather from the various accounts any estimate of the whole number of lives lost.

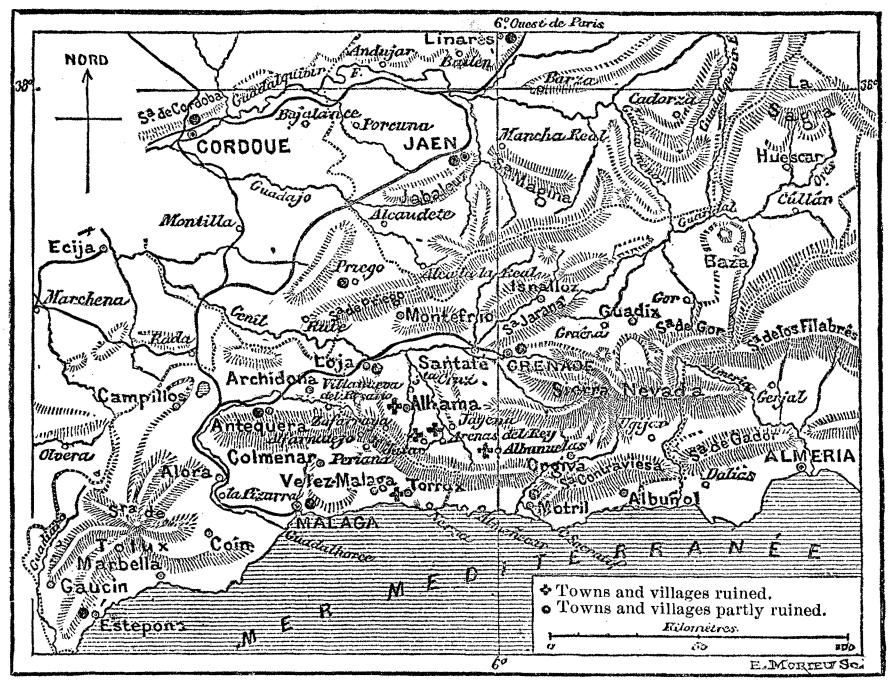


MAP OF SPAIN. THE REGION AFFECTED IS SHADED. (From *La Nature.*)

On Jan. 14 the official records stated for Granada 695 killed and 1,480 injured. Other estimates have placed the entire loss of life at upwards of 2,000. The houses destroyed are numbered by thousands, and the villages of Alhama, Santa Cruz, Arenas del Rey, Periana, and Albuñuelas are now but piles of ruins. More than thirty-five villages are named where some dead and wounded were taken from the ruins. Of the 10,000 houses in Malaga, 7,000 will require repairs.

The shock of Dec. 25 was succeeded by lighter shocks on the remaining days of the month, and at longer intervals through the month of January, and, indeed, up to the present time. A list of the shocks is as follows: —

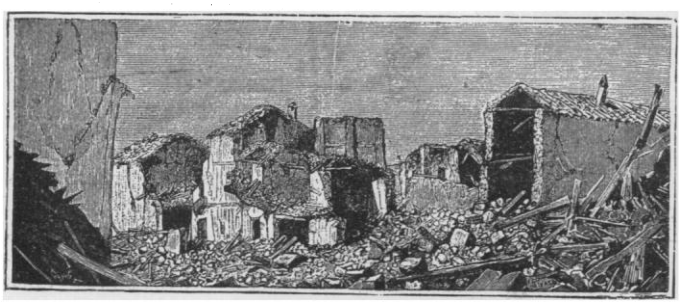
Dec. 22. Pontevedra, Vigo, Lisbon (3.29 A.M.), Madeira, Azores (2.30 A.M.).
24. Seville (light).



MAP OF THE REGION SUFFERING MOST SEVERELY. (From *L'Astronomie.*)

Dec. 25. Madrid (to the Mediterranean, etc., as above).
26. Madrid, Gibraltar, and the southern provinces.

Dec. 27. Antequera (five shocks), Archidona (nine shocks), Malaga.
28, 29. Torrox, Malaga.
30. Velez Malaga, Torrox (7 and 10 A.M.), provinces of Granada and Malaga.
31. Torrox, Granada, Jaen (6.35 P.M.), Malaga.



A RUINED STREET IN ALHAMA. (From *Cosmos*.)

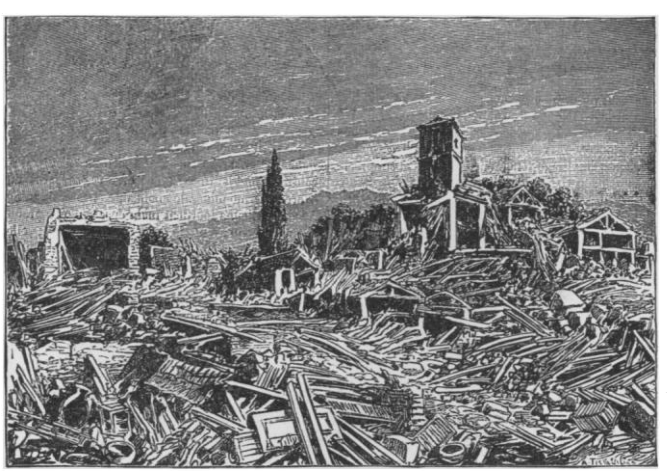
Jan. 1. Torrox, Granada (11.45 P.M.), Malaga, Nerja (2, 6.45, 9 P.M.), Algarrobo, Alhama, Antequera, Valencia.
2. Valencia, Granada, Malaga, Velez Malaga.
3. Loja, Alhama, Jaen, Velez Malaga.
5. Granada (6 P.M., severe), Loja, Motril (fifty houses destroyed), Malaga.
Jan. 7. Nerja, Velez Malaga.
8. Loja, Torrox.
9. Torrox.
10. Malaga.
11. Malaga (buildings fell).
12. Gibraltar, Alhama, Algarrobo.
13. Torrox, Canillas, Almuñecar, Algarrobo.
16. Granada (10 P.M.), Canillas, Motril.
21. Malaga, Loja, Velez Malaga, Almuñecar.
22. Periana.
27. Alhama (one person killed).
Feb. 12. Alhama.
13. Torre del Campo, forty miles north of Granada (serious damage to hospital).
14. Granada, Velez Malaga.
23. Granada (renewed shocks reported).
March 2. Granada, Loja, Alhama (houses fell).

The severe shock on Christmas night seems to have been perceived in England, having been reported as felt at 10.20 P.M. in Wilts, and also having been recorded by small disturbances of the magnets in the Greenwich observatory at 9.15 P.M.; the suspended magnets acting as pendulum seismographs.

While they may probably have no connection with the Spanish earthquake, the following shocks, felt in other parts of Europe during the same period, are worth noting; viz.,—

Dec. 25. At Zernetz, Engadine (at 8.17 and 11 P.M., the former hour corresponding to 7.32 P.M., Madrid time).
27, 28. At Tarvis in Carinthia.
28. 7 A.M. at Sundal and Öxendal, Norway.
29. In Wales.
Jan. 4. In Styria.
5. 3 A.M. at Chambéry, Savoy; 5.50 A.M. at Embrun.
Jan. 6. In Italy at Susa, near Mont Cenis, and at Velletri.
21. Between 0 and 1 A.M. at Ennenda, Glarus.

As bearing upon the possible connection between seismic and atmospheric phenomena, it is remarked that an unusually high barometer prevailed over the Spanish peninsula during the first half of December; while from Dec. 20 to 22 a heavy storm area, attended by an unusual atmospheric depression, was passing from north to south over the same region, reaching the Mediterranean on the 22d; also that at Nerja a hurricane followed the first shocks,



RUINS OF A CONVENT, ALBUÑUELAS. (From *La Nature*.)

blowing down the houses, whose walls were already weakened by the earthquake.

The geological characteristics of the country are described in the next article: it will therefore suffice here to say that the seismic phenomena seem to be intimately related to the geological growth of the mountain system, especially the Sierra Nevada, the elevation of which is apparently not yet completed. A commission, consisting of three mining engineers, under the presidency of Sr. D. Manuel Fernandez de Castro, has been appointed by the Spanish government to study this series of earthquakes, and has already distributed a list of thirty-three interrogatories relating not only to the time, direction, and other particulars of the earthquake shocks, but also to various atmospheric phenomena, such as the pressure, temperature, clouds, etc.

C. G. ROCKWOOD, Jun.

THE SIERRA NEVADA OF SPAIN: THE SCENE OF THE RECENT EARTHQUAKES.

THE Sierra Nevada of Spain, though full of interest for the tourist, the man of science, or the student of history, has been little visited, and almost nothing has been written about it.

This sierra forms a compact body, twenty-five miles wide and fifty miles long, completely isolated, and without directly connected lateral spurs or terminal ridges. Surrounded by an alluvial plain as it is, it has, nevertheless, certain smaller neighbors which seem, like itself, to have been ejected from below. Its crest has been denuded by the elements, and its sides scored by brooks or torrents which diverge in all directions from the central axis, fed by the rains of spring and the melting snows of summer. Four principal streams, descending to the north-west, meet at the very foot of the Alhambra, and unite their waters before traversing the renowned plain of La Vega. Their cascades and ripples, descending from the mountain crest above, give to the adjoining valley a delicious freshness during the torrid months of summer. To these waters is due the immense isle of verdure presented by the Vega at a time when nearly all southern Europe is scorched dry by the sun. At many points the rivers run in narrow, deep channels easily dammed. From their sources to the moment when they reach the plain, their average descent is one to ten, almost the maximum for running waters. At that point they are captured: not a drop escapes. All the irrigating works and canals, the customs governing the distribution of water, even the rules recalled by the strokes of the bell nightly from the minarets of the Alhambra, are the legacy of the Arabian civilization which blossomed on the plain before it was driven to a last refuge on the mountain.

On the north, three rivers descend to the plain of Guadiz; but, their sources not being fed by perpetual snows, when the rainy season has passed they dry away. In consequence this plain is as sterile, bare, and forbidding as that of the Vega is green and inviting. Wherever the eye wanders, apart from the sierras, lies a reddish-gray plateau of dusty alluvium, seamed and rent by precipitous cañons. Nothing recalls the idea of life: the desolation is as that of an unknown country, grand and terrible. All the valleys and plains of this part of Andalusia present the same impressive and melancholy features. Gustave Doré, who passed through this region many years ago, has profited by his experience to introduce memories of it in some of the most strange and fantastic productions of his pencil. This sterile region is poor, unpeopled, almost unknown, and practically cut off from communication with the rest of Spain.

Farther to the west is the country of the Alpujarras, so celebrated in Moorish history for the terrible conflicts of which it was the theatre. More than one poet has celebrated the combats of the Christian and the Moor in the narrow defiles and rocky gorges of the sierra; but all these imaginary descriptions fall far short of depicting the scene as it appears in reality.

The Alpujarras are composed of two cistern-like basins, absolutely closed to the outer world, except by two narrow gorges cut in the rock by the rivers which traverse them. The first of these rivers, the Rio Grande de Ujijar, descends directly from the heights of the Sierra Nevada, passes by the site of that town, and, with its affluents, waters the basin of Ujijar, the ancient capital of the little Moorish kingdom. It issues by a deep cañon, and falls into the Mediterranean by the little port of Adra at no great distance. The second, the Guadalfeo, runs between the Sierra Nevada and Contraviesa, close by the former, whose slopes it drains. Emerging from the basin, it turns abruptly to the south, reaching the sea near Motril. Just before entering the gorges of the Sierra Contraviesa, the Guadalfeo receives the brook of Beznar from a point elevated above the plain of La Vega, whence Boabdil, the last of the Moors, is said to have