repeatedly reported on unimpeachable authority along the Sespe, in Ventura County. We have had recently the Sandberg report above referred to. Two were reported in Santa Clara County, 50 or 60 miles from Oakland as the crow flies, in 1933, and the spot precisely located on a Geological Survey map, with only a slight element of doubt. The surrounding country differs but slightly from that where we watched the birds, though not usually classed as condor territory now.

The apparent ease with which our friends staged the exhibition of condors in their free state, in surprising numbers considering their rarity, tended perhaps to inspire in the minds of the spectators unwarranted optimism regarding the number remaining. Yet, even allowing for this circumstance also, the writer retains the impression that there are more of these birds in the state than is generally supposed to be the case.

As to their future prospects: The trend of their past history undeniably points to ultimate extinction unless conservation measures are promptly put into effect. The circumstance of our having seen young birds, added to the fact that condors are fairly frequently reported, does not necessarily imply that they are increasing, or even holding their own. Even a dying race may reproduce and experience temporary cyclic increases until near the end. Far better informed persons than the writer believe that, for the condor, this end is fast approaching. They need help!

Piedmont, California, November 28, 1934.

GEOLOGIC FACTORS IN THE DISTRIBUTION OF BIRDS

WITH TWO ILLUSTRATIONS

By JUNEA W. KELLY

Every student of biology at some time during the course of his studies asks himself the question "What are the causes that have led to the present distribution of plants and animals?" I feel that through the study of geology some light can be thrown on this subject.

It seems to me that the distribution of birds is both directly and indirectly influenced not only by the topography of the country but by the rock formations and soils resultant from their decay. I have barely begun my observations in this field but by presenting the material I have so far been able to gather from literature and from my own field work I might stimulate others to record their studies along these lines.

I have arranged my material under five headings beginning with the broader aspects of the relationship between geology and ornithology and ending with the more intimate relationship between the soil itself and the birds.

Great changes in land masses.—Although birds by their power of flight are able to cross great expanses of water, yet the great changes in land masses which have taken place from time to time during the past must have had their influences on avian distribution. The subsidences separated continents and formed islands. Opportunity was thus given for development without outside interference. In other cases elevations creating land bridges permitted the easy passage of species into new regions. With repeated subsidences and elevations birds of common ancestry may well have developed into different species, genera and even families. The advance of continental ice sheets must have wiped out whole orders from certain regions and crowded others into the remaining territory, thus giving rise to intense competition

and leading to differentiation of species. With retreat of the ice sheet new territory was opened up to those species best adapted to avail themselves of the opportunity. During certain geologic periods there were repeated advances and retreats of ice caps.

The disturbances just described may easily account for trogons, members of an ancient family, being now found in Africa, Asia, southern United States, Central and South America, but not in Europe where paleontology tells us they once lived. They may account for wood warblers, vireos, tanagers and hummingbirds being restricted to the New World, and rollers, hoopoes and sun birds to the Old World, while Australia has its cassowaries, lyre birds and bower birds and does not have true finches and woodpeckers. Again, pelagic species and shore birds whose territory has been less affected are now more universally distributed than species of land birds.

In this connection the New Madrid earthquake of 1811 is worthy of mention. Here in the northwestern corner of Tennessee through a combination of landslide and uplift the channel of Reelfoot Creek was dammed and Reelfoot Lake formed. Now thousands of American Egrets, hundreds of Great Blue Herons, Little Blue Herons, cormorants, several species of gulls, terns, ducks and other water birds are found on and near the lake—birds that would otherwise never have come to this part of Tennessee. It is interesting to note that Audubon was riding horseback in this vicinity at the time of the earthquake and has described the actual shock which lasted about two minutes. We are accustomed in this age of dam construction to see the effect of artificial bodies of water on bird life, but in the case of Reelfoot we see the creation of a lake by a natural phenomenon such as must have happened frequently in the geologic past.

On the other hand, it is true that on such islands as the Galapagos, six hundred miles off the coast of Ecuador, there are many land birds which may well have come from South America and the West Indies. There are other similar occurrences and many instances of erratic wanderings of birds that can be cited. One example in our Bay Region is the repeated return to Lake Merritt of a lone European Widgeon. The finding, however, of fossils of now living species that no longer inhabit the region where the fossils are found makes it seem certain that great changes in earth configuration have affected the distribution of birds.

Topography.—We think of mountains as barriers and rivers as highways for animals. Again, on account of the power of flight, birds can to a large extent surmount the barriers by flying over them or through gaps or, still further, around the ends of mountain ranges. The mountains do, however, act as barriers as they affect the climate and that in turn the vegetation and insect life available to the birds for food. Rivers not only form habitats but during the spring and fall migrations they are the natural routes followed by many of the birds on their way to and from breeding grounds, as can be observed so well along the Mississippi and Missouri rivers. Large bodies of water such as lakes, seas and oceans affect climate and therefore the fauna of a region. The topography of the shore may or may not furnish suitable habitats for birds and it also has some influence on the migration routes.

Rock decay—soil formation.—Soil is dependent on the kind of rock from which it is derived and also upon the manner of its decay. In a dry climate the weathering is largely mechanical, while in a humid one there is much solution decay. Also in the latter case many of the minerals are leached out of the soil. This difference in weathering is exceptionally well seen in comparing limestone weathering under different climatic conditions. (See Limestone weathering and plant associations of the San Francisco Region, California Journal of Mines and Geology, July and October, 1933; by Junea W. Kelly.) The chemical composition of the soil as well as its texture affects the character of the plant life and this in turn affects

the animal life that depends upon it for food.

Rock decay further influences the distribution of birds in that the resultant topography and soil may produce plains, rolling hills, swamps, marshes, deltas, beaches, and sea cliffs, thus producing habitats themselves. Still another point to be considered is that these beaches may be sandy, consisting largely of quartz grains residual of granite, as can be seen in so many places along the shore of Monterey Peninsula where the Montara granite is weathering. Again, beaches may be muddy as is the case where shales decay and where the finer particles of clay which result from the decay of the feldspars in the granites may have accumulated. The influence of the composition of the soil of our beaches upon the shore birds can be observed locally. Along the shore of Bay Farm Island, Alameda County, California, Snowy Plovers and Sanderlings are found on the sandy stretches whereas they are missing along Fernside Boulevard, Alameda, where many other species less discriminating are often found in large numbers feeding in the mud. Again, rocky shores bring us Oystercatchers, Surf-birds, Wandering Tattlers and Turnstones.

Nesting sites.—It is interesting to note the number of species of birds, as well as the wide range of families represented among the birds, which, although perhaps not dependent upon them, at least use cliffs or shelves, crevices, burrows, and depressions in the ground for nesting purposes. Possibly some that formerly laid their eggs on the bare shelf of a cliff, on account of persecution took shelter in crevices and when these were not available, but the soil permitted, formed the habit of excavating burrows. This may account for the variation of sites used by birds of the same species as seen in the case of puffins, auklets, shearwaters, petrels and others.

The following are some of the birds that use the sites previously mentioned. Cliffs are popular with cormorants, murres, vultures, hawks, swifts; crevices with auklets, puffins, guillemots, rock and canyon wrens, rosy finches; burrows in banks and cliffs with puffins, petrels, kingfishers, bank and rough-winged swallows, owls,

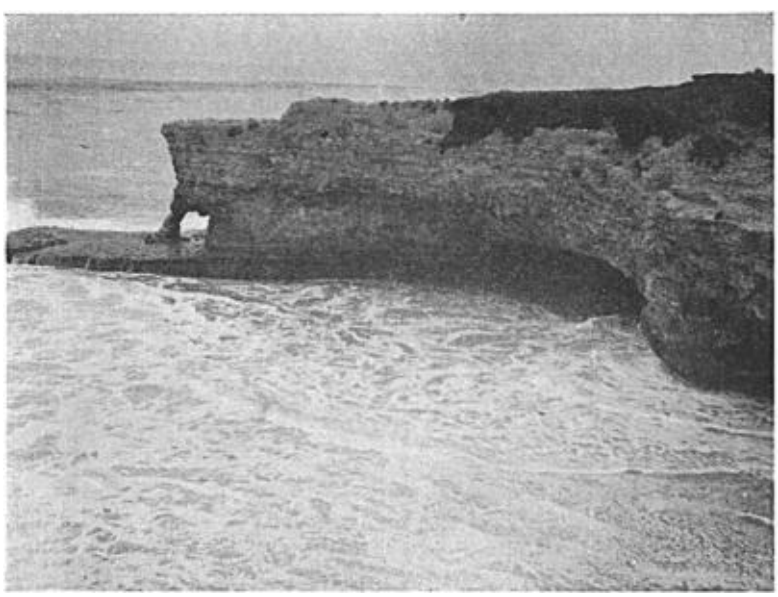

Fig. 4. Sea cliffs near Santa Cruz, showing holes frequented by Pigeon Guillemots.

ground woodpeckers of Africa, nightjars of South America; depressions with shore birds, juncos.

In order to form suitable cliffs and crevices, rocks must weather along planes of stratification, jointing, cleavage or foliation, or must form solution cavities so frequently occurring in limestone.

As an example of how restricted good nesting sites are for guillemots one need but consider the northern coast of Ireland where these birds are numerous on Troy Island and Horn Head while they are practically absent from the neighboring shore. The rocks of the cliffs used are largely gneisses and schists that weather into shelves slightly tilted landward so that the eggs will not roll off, are far enough up on the cliff that storm waves will not wash the eggs away, are surrounded by water at low tide and do not have sharp, jagged pinnacles projecting so that when the young birds leave the nesting shelves, which they do before they are capable of sustained flight, they can get into the water without injury. Deep water is near at hand where they can obtain their food easily.

Coming nearer to our own locality, along the Cliff Drive at Santa Cruz in the steep cliffs of diatomaceous shale the Pigeon Guillemots make use of the holes whence small blocks of rock, loosened by weathering, have fallen. Only a few birds nest here compared to the numbers found in Alaska. Probably our local cliffs are not sufficiently ideal to attract greater numbers of guillemots.

Cliff and Barn swallows have taken kindly to the settlement of the country. The buildings of man have given these birds an opportunity to become much more widely distributed than formerly. The species must have been local and restricted, particularly in the case of Cliff Swallows which not only require a suitable cliff but also an overhanging ledge sufficiently wide to protect their nests from the elements. Coues remarks that Barn Swallows like a corner in artificial situations, which seems a modification of their primitive hole nesting habit.

For those birds that excavate burrows the soil must be soft enough for them to handle and yet firm enough so that the burrow will not collapse. Along the road to Monterey interesting observations were made. One mile south of Sargent along the Southern Pacific tracks is a thick formation of clay, sandstone and gravel. The beds dip about 25° to the south. Here the Bank Swallows have used the sandy clay strata. Cliff Swallows and White-throated Swifts were also nesting here. In a road cut one-half mile southwest of Betabel, Bank Swallows were nesting in the sandy clay beds and not using the coarse gravelly beds nor the strata in which there was cross bedding of the material. Although the Prunedale cutoff was not as yet completed, the new road cuts were beginning to erode, showing the difference in composition of the beds and curiously enough Bank Swallows were perching on the power wires along the road as if considering the possibility of new home sites there.

For birds using depressions in the ground the soil must be such that they can scratch out same. In the case of the Wilson Phalarope the male bird makes the depression. Killdeer favor pebble strewn beaches, and sandy beaches are chosen by the Snowy Plover.

Nesting material.—Here again in looking over the list of birds that use mud in some way as nesting material one is impressed with the wide range of families involved—Flamingoes, Tri-colored and Brewer blackbirds, several species of grackles, magpies, Steller Jays, robins, some of the thrushes, Barn and Cliff swallows, Louisiana Water-thrushes (a wood warbler), Black Phoebes. Robin nests have been found in the construction of which no mud was used because none was available. The reasons were drought or too heavy a cover of forest litter, as in places on islands off the coast of Maine.

Mr. Harwell, naturalist of Yosemite National Park, tells of several attempts of a Black Phoebe to build under a bridge where only granular soil was obtainable

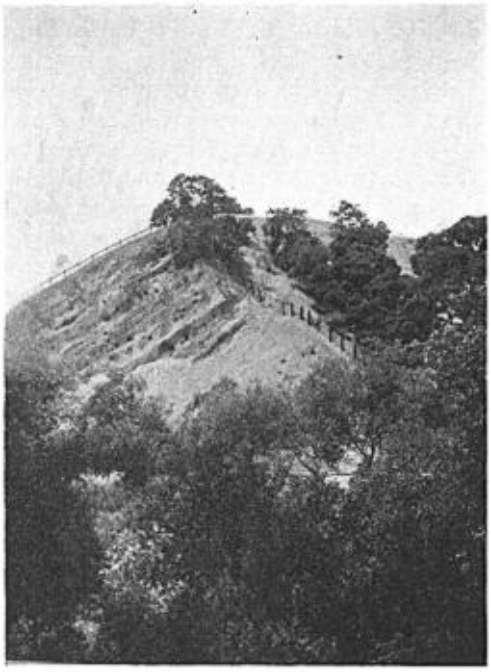

Fig. 5. Pajaro River sand banks, one mile south of Sargent, Santa Clara County, where swallows and swifts nest.

and the nests gave way before they could be used. The phoebes must nest where there are clay residuals. This would apply to all birds that are masons. At the quarry of the Silicate Company of California, twenty-four miles from Stockton on the Borden Highway, there are ideal cliffs with protecting arches where Cliff Swallows nest. The silicious sand is useless for the making of their retort-shaped nests, but fortunately there is a water trough in a cow pasture adjoining, where mud is plentiful.

Conclusion.—From the above facts it seems to me that a study of geology helps one to understand the distribution of birds. Further, that rock decay definitely restricts, at least the nesting range of such birds as Cliff Swallows and Black Phoebes, which must not only find suitable nesting sites but suitable nesting material as well—adhesive clay versus quartz sand. Therefore, unless they change their mode of life they will always be more restricted than such birds as English Sparrows and Starlings which can gain new territory rapidly because they are not restricted as to nesting sites nor material; grass, straw, and feathers can be obtained almost universally.

Alameda, California, November 18, 1934.