origin, but whether these mark the terminus of the local valley glaciers or merely recessional stages cannot be determined with any degree of certainty.

The above described features suggest that during the later part, at least, of the Vashon Glacial Stage, a lake was dammed in the valley of the South Fork of the Skykomish River by the Puget Sound glacier. An ice-marginal stream from the north emptied into the lake, forming the ice-contact delta which grew out chiefly from the north side of the valley during the deposition of warved and laminated clays in quiet water farther up the valley. The highest level at which thees clays have been found is 1100 feet above sea level, but the lake certainly filled the valley to a height of 1800 feet at the stage of maximum delta growth. Interstratification of till sheets in the delta indicate that the Puget Sound ice was by no means stagnant at the time of deposition of the valley filling sequence.

It is clear that the lower part of the mountain valley of the South Fork of the Skykomish River was not occupied by locally derived ice during a late stage of Vashon glaciation when the main ice stood at a level of 2000 feet or more opposite the valley mouth. This relation supports the views of Bretz in regard to the relative strength of local and northern ice. It must be kept in mind, however, that the features described here may be records only of the final stages of the Vashon glaciation, and that the relations of the northern and local ice may have been decidedly different earlier in the Vashon Stage. It must also be remembered that the conclusions of Willis were drawn from field work considerably to the south of the Skykomish and that it is likely that the local glaciers descending from the flanks of Mt. Rainier were larger than those of the Skykomish Valley.

[1] Bailey Willis, Drift Phenomena of Puget Sound, Geol. Soc. Am. Bull., Vol. 9, pp. 111-162, 1898.
[2] Bailey Willis, op. cit.
[3] J. Harlan Bretz, Glaciation of the Puget Sound Region, Wash. Geol. Survey, Bull. No. 8, 1913.

The State Line Earthquake at Milton and Walla Walla[1]

By BENJ. H. BROWN
Walla Walla, Washington

On two occasions in the writer's experience the senses failed to coordinate. The first time a pilot sent his airship into a tailspin and the passenger seemed to see the earth and the sky roll around over each other. The second time was at 11:05 p. m. on July 15, 1936, when the region around Milton, Oregon, and Walla Walla, Washington, was so shaken in an earthquake that many persons left their beds for the outdoors in haste and perturbation with various styles of deshabile. The writer's house at the north city limits of Walla Walla shook and rattled, and rumbled, and groaned, and squeaked, imitating closely the work of a jazz orchestra, without any permanent damage.

The first and main shock was followed by lesser aftershocks at 11:23, 11:25, 11:30, 11:56, 12:10½, 12:25, 12:27½, 12:38, 1:00, 1:10½, Western Union time, to the minute. Occasional aftershocks have been felt ever since.

Many chimneys were broken, several houses moved an inch or less on their foundations, stacks of boxed and canned goods and shelf wares were scattered over floors with some damage. In one house a half mile west of Ferndale a brick chimney broke at the roof and at the ceiling. The part above the roof was rotated and left standing. The attic portion of the chimney fell to the northward, breaking through the ceiling and strewing

bricks and mortar over the kitchen furniture. A two-story concrete house one mile west of Umapine shed some of the top of the second story wall. The owner has restored this house by moving the second story concrete and lowering the roof to make a one-story house. One fine country residence suffered the complete loss of a large fireplace chimney, and the porch of this house settled two inches, leaving the house roof extension hanging without support. The ornamental railing of cement posts on top of a cement block office building in Freewater was greatly damaged, much of it being thrown southwards to the sidewalk. A brick house at the penitentiary used by the warden has been condemned as unsafe. The writer estimates the loss at $100,000. Repairs on the Milton-Freewater school buildings cost $8500. Many cracked basement and plastered walls may never be repaired, but these are included in the estimate. Many capstones in the cemeteries were rotated, the free corner moving usually less than an inch. About 70 per cent of stones rotated clockwise, viewed from above. Stones in close proximity in some cases rotated in opposite directions.

The quake did some useful work. Several springs are reported to have been revived by the shocks. On the farm of Julius Jensen about four miles south-southwest of Walla Walla is an artesian well 600 feet deep, which, when first drilled, spouted water eight feet above the surface. As other wells were drilled, the flow weakened until a pump was installed to raise the water to the surface. The earthquake revived this well and it now throws a four-inch stream several feet from a horizontal pipe 2½ feet above the surface. This well at present shows no signs of diminishing its flow.

A spur of the Blue Mountains, known locally as the Touchet Ridge, extends from Milton west-northwest, crossing into Washington about five miles east of Wallula. The ridge crossed the Columbia River at one time, damming the water to form a large lake. The north edge of Touchet Ridge in places is very abrupt, the layers of basalt being broken square off at Milton, and marks an old fault line. North of the ridge lies the valley of the Walla Walla River and its tributaries.

Superposed on the old fault is a more recent fault extending from Milton about 20 miles down the valley. The basalt floor underlying the Milton-Walla Walla region has dropped 600 feet below the average gradient of the valley. The south edge of the depression lines up closely with the old fault line, whereas the other sides of the depression slope up gradually to surface exposures of basalt four miles east of Walla Walla, six to eight miles north of Walla Walla, and two miles west of Touchet. No evidence of fracture has been found on the east, north, and west sides.

This local depression has been the site of three successive lakes, as described in a former paper before the Northwest Scientific Association. Alternating layers of lake sediments and river gravels have accumulated to fill this area to meet the common gradient of the valley. A fourth lake in glacial times covered the depressed area with a layer of sediments whose maximum depth is known to exceed 100 feet. Most of these later sediments have been carried away by the Walla Walla River system. Thus, the depressed area has been subjected to varying loads of considerable magnitude.

Between the towns of Milton-Freewater and Umapine are several earthcracks up to three inches in width, some a few feet long, others have been traced 200 yards. The general direction of the cracks is west-northwest, or roughly parallel with the Touchet Ridge fault line. The destructive effects of the earthquake seem to be strongest along the line of these cracks. In a Milton store a small scale pen was jumped out of its socket, showing a vertical life at this point. Three or four miles

north of the line described is another line of cracks also roughly parallel to the old fault line. One crack, when examined November 15, was at least one foot wide. Possibly this width was due partly to sloughing off of the side walls, as the crack was filled to within a foot of the top by loose earth. One wall of a cut in the State Line highway running east and west slumped to such an extent that the loose dirt flowed completely across the driveway.

The buildings in the earthquake area are so irregularly distributed and their character and condition so varied that it has been impossible to fix with accuracy the destructive limits.

So much for the facts.

Now, the writer, with the characteristic abandon of the amateur, suggests that the south line of destruction marks the epicenter, and the north line marks the position where the waves emerged at the angle of greatest destruction. And, lastly, with even greater abandon, he suggests that the earthquake was due to an upsnapping of the basalt folor due to removal of the load as above described.

[1] Presented at the annual meeting of the Northwest Scientific Association, Spokane, Washington, December 29-30, 1936.

Evaluation of Jurassic Intercontinental Correlations[1]

By RALPH L. LUPHER
State College of Washington

The Jurassic faunas of Europe have been the subject of detailed study since the beginning of the 19th century. The result has been a subdivision of the European stratal and faunal sequence in a degree of detail far beyond that attained for any period in North America.

The most detailed subdivision of the Jurassic so far attempted is that of S. S. Buckman. His intensive studies of the English Jurassic faunas and stratigraphy, beginning in 1880 and ending in 1927, have resulted in a chronologic subdivision of the Jurassic period into 47 ages and 350 hemerae. Each age is named from the characteristic ammonite genus or family that reached its maximum development at that time, and hemerae, the subdivisions of ages, are named from a characteristic genus or species.

Coincident with the development of the chronologic scale Buckman undertook an extremely detailed subdivision of the stratigraphic sequence and an equally detailed subdivision of species, genera, and families of ammonites, the latter being regarded by many as excessive and unreasonable "splitting." Under Buckman's conception each species is confined to a single hemera and genera do not range through more than four ages. By way of comparison, it might be said that a genus of ammonites, as defined by Buckman, is of about the same magnitude as a species of most authors.

The marine Jurassic rocks of North America are too poor in fossils, too incomplete, discontinuous, and imperfectly known to permit the working out of their relations except by correlation with the well-known sequence of Europe. The chronology established by Buckman is gaining acceptance in this country and most of the intercontinental correlations attempted by recent workers on North American Jurassic faunas have been made in terms of this chronology. In view of the exceedingly small units proposed in Buckman's chronology of 47 ages and 350 hemerae, there arises a question regarding the exactitude with which these correlations can be made.

During the past 10 years publications on the Jurassic faunas of North America have been made mostly by F. H. McLearn and C. H. Crickmay. McLearn, working on the Jurassic faunas of British Columbia and Alberta, has been, for the most part, content to point out the affinities of his Canadian species with English species and to give the dates of those English species in terms of Buckman's chronology, implying a certain age, or part of an age, for the American species, but really leaving the reader to draw his own conclusions.

Crickmay has made extensive studies of the Jurassic faunas of North America, principally in British Columbia and United States, and has done much to call attention to the need for more exact paleontologic and stratigraphic work. He states the dates of his faunas mostly in terms of the ages of Buckman's chronology, but some dates are given in terms of hemerae. A few examples will illustrate the intercontinental hemeral correlations proposed by Crickmay. In writing on the fauna of the middle member of the Sundance formation, he states that: "The middle member contains a sparse fauna, consisting mainly of ammonites of the genus Cardioceras. . . . The date is Cardioceratan, cardia, in terms of the chronology brought together by Buckman."[2] In a paper on North American Jurassic brachiopods,[3] some brachiopod species are assigned to definite hemerae, such as mollis, Witchellia, and Epalixities, though some are referred to ages, some to stages. Eleven successive "faunas" containing one to six species each were listed for the Mormon formation of Taylorville[4] and eight of these "faunas" were referred to seven hemerae of Buckman's chronology.

For some time the writer has been engaged in a study of the central Oregon Jurassic faunas and necessarily has been much concerned with the question of how closely those faunas may be correlated with European faunas. The chronology developed by Buckman appeared to be a step in the right direction in that it proposed a sequence of time divisions which, in some modified form, might serve as a standard world-wide chronology for dating Jurassic faunas and strata. Some of the Oregon faunas appeared to permit recognition of ages, or even parts of ages, with a fair degree of certainty, but attempts to define dates in terms of hemerae always met with serious conflicting evidences. Therefore this attempt is made to bring out some facts that appear to be of importance in determining whether or not Buckman's hemerae are recognizable in North America.

Several questions must be answered in order to reach a satisfactory evaluation of hemeral correlations. Some of these questions are: (1) how nearly correct is the hemeral succession of English genera and species as outlined by Buckman; (2) how many of the hemerae are determined by local facies conditions and accident of discovery of fossil material rather than actual evolutionary differentiation of species and genera; (3) what are the bases for determining contemporaneity of European and North American faunas; (4) are these bases sufficient for the results assumed?

The first two questions cannot be answered at present. Buckman's chronoolgy is not an untried, suddenly conceived scheme—it was developed gradually over a period of more than thirty years with the benefit of much criticism. The major chronologic divisions called "ages" are frequently used by other authors, since ages are of about the same magnitude as the "zones" of other writers, but hemerae, the subdivisions of ages, have not gained general acceptance. Certainly the chronology is not correct in every detail, but sufficient time has not yet elapsed for other workers in the field to determine the validity of each hemera or to find all the inaccuracies in the supposed succession of hemerae. Since the practice of dating North American faunas in terms of Buckman's hemerae apparently assumes that the hemerae are valid chronologic units