ANNOTATED BIBLIOGRAPHY OF WASHINGTON CLAYS

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ANNOTATED BIBLIOGRAPHY OF WASHINGTON CLAYS

1. Adams, M. F., 1949, Recovery of alumina from clay: Washington State Inst. Technology Bull. 203, p. 4, 6.

Development of a combined-acid process for recovery of alumina from clay is described. Iron is separated from the alumina by exclusion of air during the precipitation and filtration steps. Also described are numerous attempts to remove silica in the acid cycle, and an economical method for production of commercial iron-free aluminum sulfate. Castle Rock clay was used in the test work.

2. Adler, H. H., 1950, Infrared investigations of clay and related minerals. In Infrared spectra of reference clay minerals: Am. Petroleum Inst. Project 49, Clay Mineral Standards, Prelim. Rept. 8, sec. 1, plates 28 and 32.

Experimental data concerning the infrared absorption characteristics of clay minerals, and consideration of theoretical aspects of infrared absorption of clays and related minerals are presented. Infrared absorption curves of two nontronite samples from Manito, Wash. are also given.

3. Allen, V. T., 1945, Effect of migration of clay minerals and hydrous aluminum oxides on the complexity of clay: Am. Ceramic Soc. Jour., v. 28, no. 10, p. 269, 270, 271, 273, 274.

Movement of montmorillonite, notronite, kaolinite, halloysite, dickite, gibbsite, and diaspore within clays after they were first formed is indicated by the relations reported in this paper. Migration of these minerals takes place rarely by transfer of their constituents as true solutions but generally as colloidal suspensions whose formation and movement are favored by conditions of good drainage and the presence of dispersing agents. This migration increases the complexity of the clays affected by it and accounts for one of the variations in the composition of a single body of clay met by the clay producer. (Author's abstract)

Washington clays discussed are: nontronite from Excelsior deposit, kaolinite filling basalt vesicles at Pullman, and diaspore filling veins and replacing structure in upper part of Cle Elum iron deposit.

4. ——————1946, Sedimentary and volcanic processes in the formation of high-alumina clay: Econ. Geology, v. 41, no. 2, p. 124-138.

This report consists primarily of an examination of the geologic history of five western clay deposits and an evaluation of the effects of sedimentary and volcanic processes at these localities. A table listing the iron minerals in these clays is also given.

The Cowlitz clay deposit near Castle Rock is described.

5. ——————1947, Some U.S. boehmite localities (abs.) : Am. Mineralogist, v. 32, nos. 3-4, p. 195.

The abstract states that boehmite occurs in Washington at the following localities: with kaolinite in the Puget shales of Eocene age at Durham, Kanasket, and Kummer, King County; with diaspore at the Cle Elum iron deposit, Kittitas County.

6. Allen, V. T., 1955, Relation of porosity and permeability to the origin of diaspore clay. In Milligan, W. O., editor. Clays and clay minerals . . .: Natl. Acad. Sciences—Natl. Research Council Pub. 395, p. 389-401.

The apparent porosity of flint, boehmite and diaspore clays bears no direct, consistent relation to the permeability of the same type of clay or to the alumina content of each type. The coefficient of permeability varies with the type and the structure of each flint clay. Diaspore clays have high permeability compared to flint clays, and the boehmite clays measured generally have a permeability intermediate between that of diaspore and that of flint clays. The apparent increase in permeability with increase in alumina content suggests that permeability has increased as silica was removed from flint clay to form boehmite and diaspore clays.

A vertical pipe of diaspore clay $1\frac{1}{2}$ inches in diameter was collected by Fred Mertens of the Laclede Christy Company at the Shockley-Thompson diaspore pit at Belle, Missouri. The pipe contains 69.16 percent alumina compared with 55.30 percent alumina for the average of the walls a few inches from the pipe. Diaspore in the pipe has vertical banding indicating it was deposited along a vertical crack. The formation of cracks in brittle flint clay is an important process in increasing the permeability and providing openings along which the ground water can migrate.

A restudy of boehmite and diaspore clays emphasizes not only a replacement of the coloform and oolitic structures of flint clays by boehmite and diaspore, a gradual alteration of flint clay to diaspore clay along fractures, and second-generation diaspore cutting early diaspore, but also the importance of secondary processes in the origin of diaspore and boehmite clays. (Author's abstract)

Diaspore occurrence in the Cle Elum iron deposits of Kittitas County is also discussed.

7. Allen, V. T., and Nichols, R. L., 1943, Cowlitz high-alumina clay deposit near Castle Rock, Washington (abs.): Geol. Soc. America Bull., v. 54, no. 12, p. 1823.

Briefly gives description of occurrence, mineral content, depositional environment, origin, and estimate of extent of the deposit.

8. Allen, V. T., and Scheid, V. E., 1946, Nontronite in the Columbia River region: Am. Mineralogist, v. 31, nos. 5-6, p. 294-312.

Composition, optical properties, source of samples, field relations, petrographic studies, and origin and migration of Washington nontronite are given.

9. Ashim, L. E., 1915, A study of the Sumas clays for refractory use: Univ. of Washington B. S. thesis, 21 p.

A brief discussion of Washington fire clay deposits is given, followed by a brief section on the geology of the Sumas deposits. Tests and analyses of 13 individual Sumas clays are given.

10. Atchison, J. A., 1942, Washington clay may answer the aluminum problem: Washington State Coll. Mining Exp. Sta. and the State Electromet. Research Lab. Inf. Circ. 46, 3 p.

A brief report dealing with the methods whereby iron impurities are sufficiently removed from the alumina in clays to warrant alumina production from Washington clays. The deposits under consideration are the Castle Rock clay, the Freeman clay, and the Mica clay.

11. ——————1944, Part I, The theory of clay beneficiation and methods for separating kaolin, silica sand, and white flake mica from eastern Washington clays; Part II, Production of alumina and aluminum metal from the kaolin: Washington State Coll. Mining Exp. Sta. and the State Electromet. Research Lab. Bull. E-2, 35 p.

Clay washing plant operations, analyses, washing tests, and flotation tests were made on eastern Washington clays. Various methods for extracting alumina from the clays are discussed, and a flow-sheet of the W. S. C. Process for production of high-grade alumina and byproducts from eastern Washington clays is presented.

12. Bethune, George A., 1891, Mines and minerals of Washington: Washington First State Geologist Ann. Rept. 1890, 122 p.

Includes a brief generalization on Washington clays and gives three analyses.

13. ——————1892, Mines and minerals of Washington: Washington First State Geologist Ann. Rept. 2, 187 p.

Includes a brief generalization on Washington clays, repeats the analyses of the First Ann. Rept. and gives three additional ones.

14. Bretz, J H., 1913, Glaciation of the Puget Sound region: Washington Geol. Survey Bull. 8, 244 p.

Gives the origin and mentions many occurrences of glacial clay in the Puget Sound region.

15. Burkhalter, Edward, 1928, The variety of clays of Washington and their adaptability to the ceramic industry: Am. Ceramic Soc. Bull., v. 7, p. 236-239.

Brief descriptions and the possible and actual utilization of clay deposits in the region surrounding Spokane.

16. Chelikowsky, J. R., 1935, Geologic distribution of fire clays in the United States: Am. Ceramic Soc. Jour., v. 18, no. 12, p. [illegible]87-[illegible]88.

Brief descriptions and data of clay deposits in 38 of the 48 States. Washington deposits discussed are: Chester-Clayton-Deer Park area, Kummer-Harris district, Sumas clays, Wenatchee clays, and Mica-Freeman district.

17. Chelikowsky, Joseph R., 1935, Geologic distribution of fire clays in the United States: Cornell Univ. Ph. D. thesis.

18. Chew, R. T., III, and Boyd, G. A., 1960, A preliminary investigation of clay deposits in Minnesota, North Dakota, Montana, northern Idaho, and Washington: Northern Pacific Railway Co., Properties and Industrial Development Dept., Geology Div., 161 p.

A detailed report on clays and clay deposits in the areas under consideration. The first portion of the report is devoted to general clay information such as origin, clay minerals, industrial classification and economics, clay products, production, economic trends, and possible commercial source of alumina.

The balance of the report is almost entirely concerned with the regional descriptions of the deposits and includes for the various delineated areas such topics as geology, description of deposits, clay products plants, plant processes and equipment, analyses and other data, and recommendations. Numerous maps and illustrations are also included.

Major Washington districts treated in this report are: Clayton-Spokane-Tekoa, Wenatchee-Cle Elum, Yakima-Tri Cities, Everett-Sumas, King County-Tacoma, and Southwestern Washington.

19. Cook, E. F., 1943, Cowlitz high-alumina clay deposit near Castle Rock, Washington: Univ. of Washington B.S. thesis, 48 p.

The geography, geology, and exploratory work at this deposit is given. Detailed information such as description of clay, drill hole data, and geologic sections on specific deposits in 9 distinct areas follows, and the concluding portion discusses the probable mining methods and costs, and the estimated reserves.

20. Culver, H. E., 1919, The coal fields of southwestern Washington: Washington Geol. Survey Bull. 19, 155 p.

Gives many sections and descriptions of shales occuring with coal.

21. Daniels, Joseph, 1914, The coal fields of Pierce County: Washington Geol. Survey Bull. 10, 146 p.

Gives many sections and descriptions of shales related to coal beds.

22. Darton, N. H., 1909, Structural materials in parts of Oregon and Washington: U.S. Geol. Survey Bull. 387, 33 p.

Mentions the occurrences of clays in Washington and quotes Landes (U.S.G.S. Bull. 285) on analyses and descriptions of deposits.

23. Davies, Ben, 1943, Correlation between the clay mineral content and the sulfuric acid extraction of alumina from some Pacific Northwest clays: Univ. of Washington M. S. thesis, 74 p.

A group of standard or near-standard clay minerals was obtained and chemical and thermal analyses were made of them for purposes of identification. The amount of acid-soluble alumina content and the percent alumina extraction were determined by a standard method. Identical tests were made on a selected group of samples obtained from high-alumina clay deposits in the Pacific Northwest. The identification and alumina-extraction results were interpreted in terms of knowledge gained on the standard minerals. In addition, several of the variables that enter the problem of the sulfuric acid extraction of alumina were studied. A method of alumina extraction is presented that might eliminate several uneconomical factors now present in most proposed processes. (from author's Scope of Investigation)

Washington clays studied were from the Castle Rock and Harris deposits.

24. Davis, D. W., and others, 1950, Electron micrographs of reference clay minerals: Am. Petroleum Inst. Project 49, Clay Mineral Standards, Prelim. Rept. 6, Plates 25 and 26.

Techniques of electron micrography and descriptions of the various clay minerals studied are given. Electron micrographs of nontronite from Garfield and Manito are included.

25. Dorisy, C. E., 1935, Index of mineral occurrences in the State of Washington: Washington State Planning Council Research Pub. 3, p. 9-11.

Brief descriptions of locations and values are given of mineral occurrences. Arrangement is alphabetical by mineral, then by county. Clays are among the minerals included in this index.

26. Engelhardt, Wolf von, 1937, Über silikatischeTonminerale: Fortschritte der Mineralogie, Kristallographie, und Petrographie, v. 21, pt. 2, p. 315,316.

Includes chemical analysis of iron-rich beidellite from Spokane.

27. Evans, G. W., 1912, The coal fields of King County: Washington Geol. Survey Bull. 3, 247 p.

Gives many sections and descriptions of shales occuring with the coal.

28. Geijsbeek, Samuel, 1911, Clay deposits of Washington: Am. Ceramic Soc. Trans., v. 13, p. 751-764.

Given are production statistics, geology of deposit areas, locations and descriptions of deposits, and chemical analyses. Ten Washington deposits are treated.

29. Glass, H. D., 1954, High-temperature phases from kaolinite and halloysite: Am. Mineralogist, v. 39, nos. 3-4, p. 195, 196-197.

30. Glover, S. L., 1935, Oil and gas possibilities of western Whatcom County: Washington Div. Geology Rept. Inv. 2, 69 p.

Gives sections and descriptions of clays and shales in connection with discussion of the possibilities of oil and gas occurrence.

31. ———— 1936, Nonmetallic mineral resources of Washington, with statistics for 1933: Washington Div. Geology Bull. 33, 135 p.

Fifty-five nonmetallic minerals, with varying market value, are described. A number of minerals of lesser economic importance are described under the heading of miscellaneous minerals. A section dealing with clays and shales describes the suitability for use of refractories, semi-refractories, and common clays and shales. Included are a list of plants operating in the State and production statistics from 1923 to 1933.

32. ———— 1941, Clays and shales of Washington: Washington Div. Geology Bull. 24, 368 p.

The origin, classification, constitution, working properties, methods of prospecting, mining and manufacturing, and tests of clays and shales are discussed. Deposits are described alphabetically by counties. Included are chemical analyses and production statistics.

33. ———— 1941, High-alumina clays: Northwest Mining News, v. 7, no. 14, p. 6.

Brief general discussion of alumina content of high-alumina clays, followed by brief remarks on Washington high-alumina clay localities.

34. Goodner, E. F., 1921, Four typical refractory clays of Washington: Univ. of Washington M. S. thesis, 70 p.

Location, nature of deposit, geologic history, and problems of preparation for use are given on the following deposits: Kummer flint clay, Freeman residual fire clay, and Clayton plastic clay. Samples from the above deposits are then discussed at length in regard to testing methods, preparation for use, various analyses, properties, and possible uses.

35. Goodspeed, G. E., and Weymouth, A. A., 1928, Mineral constituents and origin of a certain kaolin deposit near Spokane, Washington: Am. Ceramic Soc. Jour., v. 11, p. 687-695.

A residual kaolin deposit at Freeman is discussed as to mode of occurrence, abundance and description of mineral constituents, and hypotheses concerning its possible origin.

36. Grim, R. E., 1953, Clay mineralogy: New York, McGraw-Hill, p. 194, 197, 308, 371.

A comprehensive work on the study of clay minerals. Among the major topics treated are: concepts of composition, classification and nomenclature, structure, X-ray diffraction data, shape and size, iron exchange, dehydration, organic reactions, optical properties, origin and occurrence, and chemical analysis.

Data on Washington specimens include: chemical analysis of nontronite from Spokane, infrared absorption curve for nontronite from Garfield, differential thermal analysis curve of glauconite, and dehydration curve of nontronite from Spokane.

37. ——————1955, Properties of clay. In Trask, P. D., editor, Recent marine sediments: Tulsa, Okla., Am. Assoc. Petroleum Geologists, p. 471.

The properties discussed include clay mineral groups, miscellaneous clay minerals, optical properties, chemical properties, base-exchange capacity, dehydration properties, lattice structure, relation of physical properties of clay to mineral composition, relation of physical properties of clay to exchangeable bases, distribution of clay minerals, and origin. Included is the chemical composition of iron-rich beidellite from Spokane.

38. Grim, R. E., and Kulbicki, Georges, 1961, Montmorillonite — high-temperature reactions and classficiation: Am. Mineralogist, v. 46, no. 11-12, p. 1329-1369.

About forty samples of the montmorillonite group of clay minerals were studied. Chemical, cation exchange, differential thermal, infra-red, and optical data were obtained on the samples. Nontronite from Manito was among the samples included in the studies.

39. Hodge, E. T., 1938, Market for Columbia River hydroelectric power using Northwest minerals. Sec. 4 — Northwest clays, vol. 3, pt. 3 — Sources of clay for scheduled uses — Northwest Sources (Washington and Idaho). U.S. Army Corps of Engineers, North Pacific Div., p. 492-804.

A comprehensive report which includes general ceramic, metallurgic, and economic data applicable to Northwest clays and detailed geologic information on certain selected Washington deposits.

40. Hosterman, J. W., Scheid, V. E., Allen, V. T., and Sohn, I. G., 1960, Investigations of some clay deposits in Washington and Idaho: U.S. Geol. Survey Bull. 1091, 147 p.

The clays are described as to location of deposits, mode of occurrence, mineral composition, possible sources of raw material for aluminum and ceramic products, and reserves. Included are descriptions of the major deposits, geologic maps and sections, logs of drill holes, results of assays, and recommendations for future work.

41. Huntting, M. T., 1943, Inventory of mineral properties in Chelan County, Washington: Washington Div. Geology Rept. Inv. 9, 63 p.

The mineral properties are described as follows: mines and prospects under lode mining properties by mining districts; placer properties alphabetically arranged; and nonmetallic mineral properties alphabetically arranged. Properties with known locations are indicated on an accompanying map. The location, access, owner, type, analyses, description, development, production, and improvement of clay deposits are given in the section on nonmetallic mineral properties.

42. Jenkins, O. P., 1923, Geological investigation of the coal fields of western Whatcom County, Washington: Washington Div. Geology Bull. 28, 135 p.

Gives many sections of shales occurring with coal.

43. ———————— 1924, Geological investigation of the coal fields of Skagit County, Washington: Washington Div. Geology Bull. 29, 63 p.

Gives a few sections of shales occurring with coal.

44. Kauffman, A. J., Jr., 1952, Industrial minerals of the Pacific Northwest: U.S. Bur. Mines Inf. Circ. 7641, 75 p.

The availability of 24 industrial minerals in Oregon, Washington, Idaho, and Montana is briefly discussed by State under each industrial mineral name.

45. Kelly, H. J., 1948, Refractory materials of the Pacific Northwest: Raw Materials Survey Resource Rept. 3, 15 p.

Among the Pacific Northwest refractory occurrences described and discussed are clay, silica, chromite, magnesite, olivine, sillimanite, and zircon. Three Washington clay deposits are described in regard to location, type, and extent.

46. ———————— 1959, Major clay basins of western Washington and Oregon (abs.): Mining Engrg., v. 11, no. 1, p. 39.

A brief treatment of the types of clays and shales in western Washington and Oregon, together with their origin, occurrence, geologic setting and usage.

47. Kelly, H. J., Carter, G. J., and Rehm, T. R., 1963, Physical and chemical properties of some Pacific Northwest halloysitic clays: U.S. Bur. Mines Rept. Inv. 6211, 32 p.

Physical properties, descriptions of deposits, and mineralogy are given of the halloysitic clays in eastern Washington and northern Idaho. Various tests and studies were then performed upon these clays. Washington clay samples included in this report are from the Mica deposit.

48. Kelly, H. J., Strandberg, K. G., Mueller, J. I., 1956, Ceramic industry development and raw-material resources of Oregon, Washington, Idaho, and Montana: U.S. Bur. Mines Inf. Circ. 7752, p. 23-48.

The ceramic raw-material resources and industries of Oregon, Washington, Idaho, and Montana are reviewed collectively, then individually, by State. Deposits are described under county names, arranged alphabetically under each State. Included is a list of ceramic plants located in these 4 states.

49. Kelly, H. J., Strandberg, K. G., and Harris, H. M., 1956, Use of Washington bentonite as a hydroseal: Univ. of Washington Eng. Exp. Sta. Trend in Engrg., v. 8, no. 4, p. 5-11.

A bentonite deposit near the Tieton Reservoir, Yakima County, was examined. The mineralogy, chemical analyses, measurement of sealing properties, various tests, utilization, and commercial significance of the bentonite are presented.

50. Kerr, P. F., and Kulp, J. L., 1949, Reference clay localities—United States: Am. Petroleum Inst. Project 49, Clay Mineral Standards, Prelim. Rept. 2, p. 69-73.

Clay localities throughout the United States were examined. Location, geological data, information on samples, and a sketch map are given for each deposit. Washington deposits described are at Garfield, Manito, Colfax, and Valleyford.

51. Kerr, P. F., Kulp, J. L., and Hamilton, P. K., 1949, Differential thermal analyses of reference clay mineral specimens: Am. Petroleum Inst. Project 49, Clay Mineral Standards, Prelim. Rept. 3, p. 34-35, figs. 17 and 18.

A discussion of the methods, apparatus, and procedures used in differential thermal analyses is presented. Experimental results of differential thermal analyses of clays from a selected number of United States localities are given. Washington nontronite from Garfield, Manito, Colfax, and Excelsior are discussed, and thermal curves are included.

52. Kerr, P. F., Main, M. S., and Hamilton, P. K., 1950, Occurrence and microscopic examination of reference clay mineral specimens: Am. Petroleum Inst. Project 49, Clay Mineral Standards, Prelim. Rept. 5, p. 10-11, 42, 51, 54, plate 3.

Mode of origin and microscopic examination data of clay mineral specimens from a number of well known localities in the United States are given. Washington specimens consist of nontronite from Garfield and Manito.

53. Kerr, P. F., and others, 1950, Analytical data on reference clay materials: Am. Petroleum Inst. Project 49, Clay Mineral Standards, Prelim. Rept. 7, p. 23, 55, 80-81, 89, 96, 114, 128, 132, 133, 141, 155.

Clay specimens from localities in the United States and Europe were examined. Data on these specimens include X-ray diffraction measurements, chemical analyses, pH data, differential thermal analyses (European clays), optical properties (European clays), semi-quantitative spectrographic analyses, base-exchange data, magnetic susceptibility, particle size determinations, and staining tests. Nontronite specimens from Garfield and Manito were included in the examination.

54. Krynine, P. D., 1939, Paleogeography of a glacial clay from Washington: Pennsylvania Acad. Sciences Proc., v. 13, p. 79-88.

Sample was of glacial clayey silt from Grand Coulee Dam site. Included in the article are general description, mineral composition, mechanical analyses, and origin of the silt.

55. Landes, Henry, 1902, The nonmetalliferous resources of Washington, except coal: Washington Geol. Survey Ann. Rept. for 1901, v. 1, pt. 3, p. 161-213.

Occurrence and description of deposits are given of building and ornamental stones, clay materials, limestone, road-making materials, and petroleum. A section dealing with soils in general, and Washington soils in particular, is also included. The section on clay materials gives details concerning the deposits owned by the Denny Clay Company, Little Falls Fire Clay Company, and the Washington Brick, Lime and Manufacturing Company.

56. ——————1905, Clay deposits of Washington: U.S. Geol. Survey Bull. 260, p. 550-558.

Gives some statistics on clay products and production, and describes deposits in the vicinity of Seattle, Spokane, Sopenah (Vader), and Yakima.

57. ——————1906, Cement resources of Washington: U.S. Geol. Survey Bull. 285, p. 377-383.

Gives analyses and brief descriptions of clays in Ferry, King, Okanogan, San Juan, Skagit, Snohomish, Stevens, and Whatcom Counties, and discusses their utilization in the manufacture of Portland cement.

58. ——————1914, The mineral resources of Washington, with statistics for 1912: Washington Geol. Survey Bull. 11, 53 p.

Lists the clay plants operating in the State and gives statistics on production from 1905 to 1912. Includes map showing location of plants.

59. ——————1934, The mineral resources of the Columbia River in eastern Washington and parts of northern Idaho; Appendix 1 of report entitled "Columbia River and Minor Tributaries": 73d Congress, 1st Session, House Document 103, v. 2, p. 1068-1076.

Includes a general account of Washington clays and the clay industry.

60. McHenry, J. R., 1952, Clay mineralogy of Recent glacial alluvium soils of western Washington: Soil Science, v. 74, no. 4, p. 281-285.

Soil samples of the Pilchuck, Sultan, Puyallup, and Puget soil series were collected in the Puyallup River Valley near Puyallup. The clay mineral content was determined by various procedures. Included data are on differential thermal analysis, pH, and exchange capacity.

61. Mackin, J. H., 1937, Varved clay section in the Puget Sound area (abs.): Geol. Soc. America Proc. 1936, p. 318.

Briefly describes the depositional sequence of a section of varved glacial clays exposed in Beacon Hill, a drumloidal hill in Seattle.

62. ——————1949, Engineering geology of West Seattle: Univ. of Washington Engrg. Exp. Sta. Trend in Engrg., v. 1, no. 3, p. 24-26.

Although not dealing with the mineralogical or commercial aspects of a clay deposit, this report on a slumping problem in West Seattle does present a lithologic picture of a clay deposit underlying one of Seattle's hills.

63. March, C. C., 1943, Alumina from clays — I, beneficiation of Washington residual clays to increase the alumina content: Washington State Coll. Mining Exp. Sta. and the State Electromet. Research Lab. Bull. E-3, 13 p.

Various tests were made on specimens of Mica-Freeman clay in order to find a means of producing alumina of a grade acceptable to the aluminum industry. Flow sheets and results of these tests are included.

64. Mark, Helen, 1963, High-alumina kaolinitic clay in the United States (exclusive of Alaska and Hawaii): U.S. Geol. Survey Mineral Inv. Resource Map MR-37, 1 sheet accompanied by 22 p. of text.

The map shows the location of mines or pits, prospects, and areas of high-alumina kaolinitic clay in the conterminous U.S. The test accompanying the map consists mainly of a locality index which is keyed to the map. The index gives the names of the deposits which are arranged by county, and also gives selected references.

Twelve Washington localities are listed.

65. Marshall, N. J., 1955, A study of the fundamental properties of Puget Sound glacial clays: Univ. of Washington M.S. thesis, 81 p.

Detailed laboratory tests data, X-ray diffraction analyses data, and base exchange data are given on tests made on the Superior clay from the West Marginal Way pit in Seattle.

66. Mielenz, R. C., and King, M. E., 1955, Physical-chemical properties and engineering performance of clays. In Pask, J. A., and Turner, M. C., eds., Clays and clay technology; Proceedings of the First National Conference on Clays and Clay Technology: California Div. Mines Bull. 169, p. 201, 207, 215, 222, 225, 226, 232, 241, 248.

Fabric (texture and structure) and mineralogic composition determine the response of clays and shales to events occuring during construction and operation of engineering works. A new system of classification of the fabric of earth materials is proposed. Characteristic mineralogic composition of clays and shales, especially in the western United States, is described. Fabric and composition are correlated with soil mechanics properties and engineering performance. Needed research on clays and shales as a basis for design, construction, and maintenance of engineering structures is emphasized. (Author's abstract)

Data and illustrations concerning several Washington clays and shales are presented.

66A. See last page.

67. Nichols, R. L., 1945, Preliminary report on the Cowlitz high-alumina clay deposit near Castle Rock, Cowlitz County, Washington: U. S. Geol. Survey open-file report, 18 p.

Sixty-seven drill holes had a total of 5,866 ft. The high-alumina clay is interbedded with marine and continental Tertiary sediments, the 6 ore bodies found are nearly flat-lying, the ores consist mainly of white, gray, and lignitic clay, and the principal ore minerals are kaolinite, gibbsite, montmorillonite, and beidellite-nontronite.

Reserves calculated by the perpendicular bisector method are: 8,634,000 dry tons of measured ore with 30.01 percent available Al_2O_3 and 5.74 percent available Fe_2O_3, and 9,249,000 dry tons of indicated ore with 29.04 percent available Al_2O_3 and 6.26 percent available Fe_2O_3. Inferred ore in the district may be between 10 and 20 million tons. (From author's abstract)

68. ——————— 1946, Preliminary report on the King County, Washington, high-alumina clay deposits: U. S. Geol. Survey open-file report, 28 p. plus 13 p. of tables.

Six high-alumina clay deposits were investigated. Twelve diamond drill holes had a total of 1724.5 ft. The high-alumina clay is interbedded with late Eocene sandstone, siltstone, shale, and coal. It is usually between 10 and 30 ft. thick, in most places it has a dip of more than 20 degrees, and it is commonly buried by landslide and glacial deposits. The ore minerals are mainly kaolinite and boehmite but gibbsite and alumina gel are also present. Siderite is in places abundant and it has an erratic distribution. The clay is gray, fine-grained, flint and semiflint, and the total Al_2O_3 content may be as high as 50 percent. It was deposited mainly as kaolinitic clay in a lacustrine environment.

Reserves calculated by the perpendicular bisector method are: 1,747,000 dry tons of measured ore with 33.0 percent available Al_2O_3 and 11.17 percent available Fe_2O_3, and 2,048,000 dry tons of indicated ore with 33.0 percent available Al_2O_3 and 11.39 percent available Fe_2O_3. Geologic data suggest there are 20,000,000 dry tons of inferred ore of approximately the same grade. (From author's abstract)

69. Northern Pacific Railway Company, Land Dept., Geological Div., 1941, Tabulated summary of special geologic reconnaissance reports, Washington and Idaho, 20 p. plus 46 p. index map supplement.

Data on a large number of minerals in Washington and northern Idaho are presented in tabular form. The data include: location, geologic occurrence, origin or type of deposit, quality, assays and analyses, estimated tonnage, present and future status, and pertinent remarks. Index maps indicate occurrences. Washington high-alumina and common clays are included.

70. Osthaus, B. B., 1954, Chemical determination of tetrahedral ions in nontronite and montmorillonite. In Swineford, Ada, and Plummer, Norman, editors. Clays and clay minerals ...: Natl. Acad. Sciences — Natl. Research Council Pub. 327, p. 404-417.

Samples of nontronite and montmorillonite were digested with dilute hydrochloric acid for various periods of time. Chemical determinations of the acid-soluble ions were made for each period of digestion. Curves are presented showing the rates of solution of these minerals as decreasing exponential functions of time. A change in the slopes of the curves, as plotted on semilogarithmic paper against time on the linear scale, suggests different rates of solution for the ions in the tetrahedral and octahedral layers. The initial slope of the curves represents the simultaneous rates of solution of the octahedral and tetrahedral layers with the octahedral layer predominating. The second slope of the curves

represents the rate of solution of the tetrahedral layer predominantly. Extrapolation of this slope to zero time is thought to give the percent of the tetrahedrally substituted ions within very close limits. Solubility curves of nontronite suggest the presence of both iron and aluminum in the tetrahedral layer. The solubility curves for Polkville montmorillonite indicate there is no substitution for silicon in the tetrahedral layer. Experimental values of tetrahedral substitution in nontronite check very closely with values postulated from the theoretical calculations obtained from the chemical analysis of the mineral. (Author's abstract)

The nontronite used in this study is from Garfield, Wash.

71. ———— 1956, Kinetic studies on montmorillonite and nontronite by the acid-dissolution technique. In Swineford, Ada, editor. Clays and clay minerals: Natl. Acad. Sciences-Natl. Research Council Pub. 456, p. 301, 304, 320-321.

Studies, including chemical analyses, acid-dissolution analyses, and related data, were made of nontronite from Garfield.

72. Page, G. A., 1931, Studies of Pacific Northwest kaolins: Univ. of Washington M.S. thesis, 159 p.

The stratigraphy of the eastern Washington-northern Idaho region is briefly presented, followed by theories of origin, geology, and characteristics of the kaolin deposits found in this region. Methods of purification, various testing methods and possible utilization as paper filler are included. Washington deposits of kaolin discussed are the Freeman and the Mica deposits

73. Pardee, J. T., and Bryan, Kirk, 1926, Geology of the Latah formation in relation to the lavas of the Columbia Plateau near Spokane, Washington: U.S. Geol. Survey Prof. Paper 140-A, p. 1-16.

Presents the geology of the formation that contains some of the best clays of the Spokane-Clayton area and describes many occurrences of clays and shale.

74. Pask, J. A., 1943, Thermal analysis of clay minerals and acid extraction of alumina from clays: U.S. Bur. Mines Rept. Inv. 3737, p. 21-28.

Chemical and thermal analyses of a number of known clay minerals were examined to determine the characteristics by which they may be identified. The available or acid-soluble alumina content and the percentage extraction were determined by a method developed by the Bureau of Mines. Identical tests were made on selected samples from some clay deposits in the Pacific Northwest. A pressure-digestion method was used on several samples with good success and offers possibilities for further study. (From author's introduction)

Among the samples described and tested are 5 from the Castle Rock area, and 1 from the Harris mine, 7 miles east of Renton.

75. Patty, E. N., and Glover, S. L., 1921, The mineral resources of Washington, with statistics for 1919: Washington Geol. Survey Bull. 21, 155 p.

Lists the clay plants operating in the State and gives statistics on production from 1913 to 1918. Includes map showing location of plants.

76. Popoff, C. C., 1945, Green River high-alumina clay deposits, Project #1202, King County, Washington: U.S. Bur. Mines War Minerals Rept. (open file), 21 p. plus 34 p. of analyses.

The Durham, Kanasket, Kangley, Blum, and Kummer deposits in the Green River area were examined by U.S. Bureau of Mines engineers. Pertinent information on these deposits includes location, ownership, sampling data, drill hole data, geologic occurrence, description, clay minerals found, reserves, development, suggested mining methods and estimated costs, and analyses. Geologic maps and sections are included.

77. ———————— 1955, Cowlitz clay deposits near Castle Rock, Wash.: U.S. Bur. Mines Rept. Inv. 5157, 60 p.

Exploration of these clay deposits by the U.S. Bureau of Mines in 1942-43 proved that high-alumina clays, suitable for open-pit mining at low cost, occur in areas 20 to 75 acres in size. The most valuable clays are confined to a 50-foot bed overlying volcanic breccia; both formations presumably are of early Tertiary age. These clays are semiflint and semiplastic and consist of kaolinite-halloysite, gibbsite, and montmorillonite.

A total of 11 million short tons of measured and indicated clay reserves is estimated on a dry basis. The clays average 29.7 percent of available alumina and 6.3 percent of available ferric oxide. The known reserves may be materially increased by additional exploration.

Preliminary tests of samples of Cowlitz clays indicate that 90 or more percent of the available alumina can be extracted by hydrometallurgical methods.

Geologic map and sections, and drill hole logs are included. (from author's introduction)

78. Riley, R. R., 1952, Pacific Northwest clays and shales for possible use as lightweight aggregates: Univ. of Washington M.S. thesis, 72 p.

Discussed are the types of lightweight aggregates, their properties and methods of production; experimental procedures for testing; test results; and recommendations for future work. Nineteen Washington clay and shale samples were used in the tests.

79. Riley, R. R., Mueller, J. I., and Shapiro, H. L., 1953, Lightweight aggregates from Pacific Northwest clays and shales: Univ. of Washington Engrg. Exp. Sta. Trend in Engrg., v. 5, no. 2, p. 4-9.

A series of preliminary tests were made on 10 shale samples and 1 glacial clay sample from Washington, and 1 siltstone sample from Oregon. The results of these tests indicated that clays are available within the State that would be satisfactory for the production of a lightweight aggregate on a commercial scale.

80. Ross, C. S., and Hendricks, S. B., 1945, Minerals of the montmorillonite group, their origin and relation to soils and clay: U.S. Geol. Survey Prof. Paper 205-B, p. 31, 32, 34, 35, 42, 43.

A detailed study of the montmorillonite group of clay minerals is presented. This study includes: nomenclature, crystal structure, location and description of analyzed clays, chemical analyses, impurities, minor constituents, base exchange, mineralogy, thermal studies, optical properties, electron-microscope photographs, synthesis, origin and mode of occurrence, and relationship of pyrophyllite and talc.

Specimens of montmorillonite-beidellite from Spokane, and nontronite from near Spokane are among those examined.

81. Saunders, E. J., 1914, The coal fields of Kittitas County: Washington Geol. Survey Bull. 9, 204 p.

Gives many sections and descriptions of shales occurring with coal.

82. Scheid, V. E., 1946, Excelsior high-alumina clay deposits, Spokane, Washington: Johns Hopkins Univ. Ph. D. thesis.

83. Scheid, V. E., 1946, Preliminary report on Excelsior high-alumina clay deposit, Spokane County, Washington: U.S. Geol. Survey open-file report, 66 p.

This report deals with the extent, geologic occurrence, geologic conditions affecting mining, areal geology, description of the clay bodies, and reserves of the Excelsior high-alumina clay deposit near Spokane. Included are chemical data, ore data, drill hole logs, and titania content data.

84. Scheid, V. E., Hosterman, J. W., and Sohn, I. G., 1954, Excelsior high-alumina clay deposit, Spokane, Washington: U.S. Geol. Survey open-file report, 77 p.

85. Shapiro, H. E., 1952, Production of lightweight concrete aggregate from Pacific Northwest clays and shales: Univ. of Washington M.S. thesis.

86. Shedd, Solon, 1910, The clays of the State of Washington; their geology, mineralogy, and technology: Pullman, Wash., State Coll. of Washington, 341 p.

A comprehensive report on Washington clays. Topics treated are: mode of occurrence, classification, types, chemical properties, physical properties, uses, suggestions in regard to prospecting, mining and preparation, formation of clay wares, drying and burning of clay ware, types of Washington clays, descriptions of Washington clay deposits and plants by county, discussion of existing and future development of the Washington clay industry, statistics of clay products in Washington, and chemical analyses.

87. ———— 1910, The clays of the State of Washington, their geology, mineralogy, and technology: Stanford Univ. Ph.D. thesis.

88. ———— 1913, Cement materials and industry in the State of Washington: Washington Geol. Survey Bull. 4, 268 p.

Types of hydraulic cements, their constituents, types and composition of raw materials used, the manufacture of portland cement, and a history of the cement industry are dealt with in the earlier chapters of this report. Detailed information on cement materials occurrences and plant operation in Washington, arranged by county, follow. Included are analyses of limestones, clays and shales, U.S. Govt. specifications for portland cement, and maps of various deposits. Information on clays and shales is incorporated throughout the body of the report.

89. ———— 1924, The mineral resources of Washington, with statistics for 1922: Washington Div. Geology Bull. 30, p. 152-159.

Lists the clay plants operating in the State and gives statistics on production from 1913 to 1922.

90. Skinner, K. G., and Kelly, H. J., 1949, Preliminary ceramic tests of clays from seven Pacific Northwest deposits: U.S. Bur. Mines Rept. Inv. 4449, 59 p.

Tests were made on samples from 7 clay deposits in Washington, Oregon, Idaho, and Montana. Test data and results, as well as maps and sections are given for each deposit. Washington clay deposits sampled for these tests are the Cowlitz, Five Mile Prairie, and Excelsior.

91. Sohn, I. G., 1952, Industrial clays, other than potential sources of alumina of the Columbia Basin: U.S. Geol. Survey Circ. 158, p. 8-13, 14-16, 17.

The location, description and use of approximately 180 Washington deposits of industrial clay (brick and tile clay, pottery clay, slip clay, and bentonite) in the Columbia Basin are given, together with a map showing the locations of these deposits.

92. ———————— 1952, Geologic environment map of alumina resources of the Columbia Basin: U.S. Geol. Survey Mineral Inv. Resources Appraisals Map MR-1, map and text on one sheet.

The geologic map shows areas containing high-alumina clay deposits of varying origins and areas with rocks not genetically related to clay deposits in the Columbia Basin. Two inset maps of the same region show brick and tile clay deposits, and pottery clay, slip clay, and bentonite deposits. Included is a generalized geologic section and profile across the region.

The text deals with the geologic factors influencing the occurrences of high-alumina clay deposits, the types of aluminous deposits, the reserves, and the potential byproducts. A table of chemical analyses of potential alumina ores is given, as well as a list giving the type and location of high-alumina clay deposits in the Basin, including 50 deposits in Washington.

93. Stringham, Bronson, and Taylor, Allen, 1950, Nontronite at Bingham, Utah: Am. Mineralogist, v. 35, nos. 11-12, p. 1060-1066.

This article deals mainly with the nontronite occurring at Kennicott Copper Mine at Bingham, Utah. Differential thermal analysis curves of nontronite from Colfax were used as a check because the Colfax nontronite is considered to be authentic.

94. Subbarao, E. C., 1953, Study of the fundamental properties of Puget Sound glacial clays: Univ. of Washington M.S. thesis, 74 p.

Superior clay from the West Marginal Way pit in Seattle was selected as most representative of the Puget Sound glacial clays. Various analyses and tests were made on Superior clay samples, and the experimental procedures are described.

95. Thomle, O. A., and Hammer, A. A., 1907, Study of the rocks and clays of the Mica Peak region: Washington State Coll. B.S. thesis.

96. Tullis, E. L., and Laney, F. B., 1932, The clays of Tertiary age in northern Idaho and eastern Washington (abs.): Pan-Am. Geologist, v. 58, p. 152-153; Northwest Science, v. 6, p. 30.

This paper discusses the distribution, extent, present and possible utilization and reserves of the white clays of this region. The classification and geological occurrence, as well as the mineralogical composition and origin, of the clays are discussed.

The deposits are located in Latah, Benewah, and Kootenai Counties, Idaho, and in Spokane, Stevens, and Whitman Counties, Washington. Deposits are numerous and in many cases of wide extent; reserves probably as great as in certain other parts of the U.S. At present the clays are confined to the making of fire brick, face brick, and structural wares, and are sold raw as prepared fire clay. Research work has shown that some of the material can be refined and made into a good grade of china clay. The clays are considered as two types, residual and transported, and occur along the margin of the Columbia basalt against the older rocks. The residual type consists of a group of the "kaolin minerals," largely kaolinite, together with quartz, micas and

accessory minerals of the original rock. The transported clays consist of essentially the same minerals with the kaolin minerals present in a greater concentration than in the residual clay. These were deposited in lakes and ponds formed in middle Tertiary time by the outpouring of the basalt. Two possible modes of origin, hydrothermal and weathering, are discussed, and it is concluded that the evidence obtained favors the latter. (Authors' abstract, slightly altered)

97. U.S. Bureau of Mines Mineral Resources of the United States, 1924-1931.

Contain statistics on clay and clay products and production.

98. U.S. Bur. Mines Minerals Yearbook, 1932-1961.

Contain statistics on clay and clay products and production.

99. U.S. Bur. Mines Minerals Yearbook, Statistical Appendix, 1932-1935.

Contain statistics on clay and clay products and production.

100. U.S. Census Bureau Reports.

Contain statistics on clay products manufacture.

101. United States Geological Survey, 1962, Clay in Washington and Idaho. In Geological Survey Research 1962; synopsis of geologic, hydrologic, and topographic results: U.S. Geol. Survey Prof. Paper 450-A, p. 7.

Geologic studies by J. W. Hosterman have delineated several areas of clay in a belt across the southern part of the Greenacres quadrangle, Washington and Idaho. Four types of clay can be distinguished on the basis of their parent material or extent of transport. Three are residual clays formed during the Tertiary by intense weathering processes that affected (1) metamorphic rocks of probably Belt or pre-Belt age, (2) granodiorite and related rocks of Late Jurassic or Cretaceous age, and (3) Columbia River Basalt of Miocene to Pliocene (?) age. The fourth type is transported clay with occurs in the Latah Formation of Miocene age. Some of the clay in the Latah Formation, however, may be residual. (Entire text of article cited.)

102. U.S. Geol. Survey Mineral Resources of the United States, 1882-1923.

Contain statistics on clay and clay products and production.

103. Valentine, G. M., 1960, Inventory of Washington minerals—Pt. 1, Nonmetallic minerals. 2d ed., revised by M. T. Huntting: Washington Div. Mines and Geology Bull. 37, pt. 1, v. 1, 175 p.; v. 2, 83 p.

This complete list of nonmetallic mineral occurrences in Washington gives brief descriptions of deposits of 95 different industrial minerals and rocks. Occurrences are described in each of the state's 39 counties; 42 commodities occur in Okanogan County, 31 in Chelan County, 25 in Ferry County, and 24 in King County. About 2,000 sand and gravel deposits are listed, with deposits in each county. Basalt is found in all but 3 counties in the state, and peat in 28 counties. The locations of all deposits are shown on the 39 maps which comprise v. 2 of the report. (Reviser's abstract.)

Clays are treated in 2 sections: common clays and shales; and refractory and semirefractory clays and shales, and special clays.

104. Van Houten, F. B., 1953, Clay minerals in sedimentary rocks and derived soils: Am. Jour. Science, v. 251, no. 1, p. 64.

Forty-three samples of sedimentary rocks and derived soils at numerous localities in the United States were examined for their clay mineral content. One of the samples was the Palouse silt loam from near Pullman.

105. Washington Div. Mines and Geology unpublished notes.

106. Weaver, C. E., 1916, The Tertiary formations of western Washington: Washington Geol. Survey Bull. 13, 327 p.

An extensive report on the age, characteristics, and extent of shales and other Tertiary rocks in western Washington.

107. ———— 1920, The mineral resources of Stevens County: Washington Geol. Survey Bull. 20, 350 p.

Includes general information on the clays of Stevens County and discusses briefly those of the Clayton (including the Abbott, Neafus, and Conner pits), Kettle Falls, Chewelah, Colville, Northport, and Valley areas.

108. ———— 1937, Tertiary stratigraphy of western Washington and northwestern Oregon: Univ. of Washington Pubs. in Geology, v. 4, 266 p.

A very comprehensive report on the geology of the formations that contain the usable shales of western Washington.

109. White, W. A., and Pichler, Ernesto, 1959, Water-sorption characteristics of clay minerals: Illinois Geol. Survey Circ. 266, p. 2, 7, 8.

This investigation was made in order to determine the water-sorption characteristics of clay and other mica minerals and to study the relation between such water sorption and the properties of soils and sediments that contain the clay minerals.

Samples of kaolinite, montmorillonite, mica, chlorite group, and sepiolite-attapulgite-palygorskite group were tested in a modified Enslin apparatus, and water sorption was read at increasing time intervals. Sorption curves were plotted as semilogarithmic graphs.

The data show that montmorillonite adsorbs more water than kaolinite, illite, and chlorite. The chlorites and illites have similar water-sorption properties. Mixtures of clay minerals and mixtures of clay minerals and sand tend to have water-sorption properties proportional to the percentage of clay mineral present. (Authors' abstract)

Nontronite from Spokane was used in the tests and a water-sorption curve for it is given.

110. Wilson, H., 1923, The clays and shales of Washington; their technology and uses: Univ. of Washington Eng. Exp. Sta. Series Bull. 18, 224 p.

A very comprehensive report on properties of clays and clay testing. Among the topics discussed are ceramic products statistics, geologic environment and age of the deposits, data on testing methods and results for Washington clays and clays outside of Washington, the typical clays of Washington and their comparison with several standard clays. Included is an index of clays by counties.

111. Wilson, H., and Goodspeed, G. E., 1934, Kaolin and china clay in the Pacific Northwest: Univ. of Washington Eng. Exp. Sta. Series Bull. 76, 184 p.

A very comprehensive report on the kaolin deposits of eastern Washington and northern Idaho. Other white clays, buff-firing clays, and miscellaneous clay and rock outcrops are also considered.

Among the topics treated in regard to the various kaolin deposits are: geologic environmental factors, mode of origin, various tests, purification, uses, mineralogical composition, chemical analyses, and production and importation statistics.

112. Wimmler, N. L., and others, 1944, Exploration of five western clay deposits: Am. Inst. Mining Metall. Engrs. Tech. Pub. 1739, p. 1-10.

The U.S. Bureau of Mines has conducted detailed exploration of the following high-alumina clay deposits: Molalla and Hobart Butte deposits in Oregon, the Cowlitz-Castle Rock deposit in southwestern Washington, the Olson deposit in Idaho, and the Ione deposit in California. This paper deals mainly with the general procedure and the methods employed, and records the pertinent details of the results obtained.

A total of 738 holes for a footage of 49,367 feet were drilled in the areas listed.

These five major deposits within their explored limits are estimated to contain 174,714,000 natural or wet tons of measured clay and 52,928,000 tons of indicated clay ranging from 23.5 to 30 percent in available alumina on a dry basis.

This exploration has proven ample quantities of clay, suitable for the production of alumina, to be available in each of these major deposits. Numerous other deposits located within reasonable distances from them can be considered contributory sources of large additional quantities of similar clay. (From authors' abstract)

113. Winchell, A. N., 1945, Montmorillonite: Am. Mineralogist, v. 30, nos. 7-8, p. 510-518.

Composition, analyses, and optic properties of 52 montmorillonite samples are given, including beidellite from Spokane.

114. Young, G. E., 1924, Workable clay deposits in the City of Seattle: Univ. of Washington B. S. thesis.

66A. Moen, W. S., 1962, Geology and mineral deposits of the north half of the Van Zandt quadrangle, Whatcom County, Washington: Washington Div. Mines and Geology Bull. 50, 129 p.

The north half of the Van Zandt 15-minute quadrangle contains deposits of limestone, quartz, and refractory clays in both quantity and quality to meet the requirements of certain mineral industries. Although gold, copper, chromite, and iron are present, the quantity and (or) quality of the metals are not favorable for profitable mining operations under present economic conditions. At present (1961), the mining operations in the area are confined to the limestone deposits. (from author's abstract).

The section on clays presents detailed information such as geology of the deposits, stratigraphic sections, mining operations, working properties, chemical analyses, conditions of deposition, and age and correlation of the Sumas fire clay deposits. A brief discussion including chemical analyses of glacial clays in the area is also given.