THE PRIMARY WATER ARTICLE THAT WIKIPEDIA DELETED – 11/2016

Primary water refers to earth-generated water (H_2O, in all its phases) produced from primary rocks which are also the source of our primary minerals**.** The emerging multi-disciplinary science of Geo-Hydrology (as opposed to Hydro-Geologyand traditional Hydrology) focuses specifically on investigating and locating primary water and is related to Geo-Chemistry, Geo-Physics, Mineralogy, Geology, Geomorphology, Seismology, Crystallography and Volcanology, as well asAstro-Biology which studies the creation of planetary water and thus life throughout our Solar System and the Universe. Primary water is created by the electromechanical forces of our planet, subjected to tremendous pressures and temperatures, both near surface and deep in the hydrous mantle transition zone, at a depth of 410-660 kilometers (250–400 miles), that has been identified by deep-earth seismologists, mineralogists and astro-biologists.[1,2,3,4,5,6,7,8]

The term[9] primary water dates to a scientific paper in the Geological Society of Stockholm Proceedings of 1896 by renowned Finnish-Swedish geologist, mineralogist and explorer Adolf Erik Nordenskiöld titled, "About Drilling for Water in Primary[10] Rock"[11] for which he was nominated[12] for the first Nobel Prize in Physics. Nordenskiöld died in 1901 before the first prizes were awarded. This paper was translated into English and included in what is considered to be the primary water textbook, "New Water for a Thirsty World" by University of Southern California professor Dr. Michael Salzman published in 1960, with a forward by Aldous Huxley, and which largely traces the career of the German-educated mining engineer and pioneer primary water geo-hydrologist Stephen Riess.[13] Such leading scientists as Nobel Prize winners Linus Pauling[14] and Willard Libby[15] as well as the eminent geologist Ralph Arnold[16] collaborated with Salzman during the four years he spent researching the subject as a result of numerous news articles chronicling Riess's exploits during the 1950s.[17,18,19,20,21,22,23,24,25,26,27,28] It was Riess who introduced the term primary water into English and the scientific lexicon by calling "the new water he finds 'primary' water because of its close association with primary minerals."[29] In 1957, Encyclopedia Britannica's Book of the Year wrote the following on *The "New Water" Theory of Stephan Riess*:[30]

“Stephan Riess of California formulated a theory that "new water" which never existed before, is constantly being formed within the earth by the combination of elemental hydrogen and oxygen and that this water finds its way to the surface, and can be located and tapped, to constitute a steady and unfailing new supply.”

— *1957 Brittanica Book of the Year*

The non-profit Primary Water Institute[31] was founded in 2014 by longtime Riess protege Pal Pauer to educate and train the next generation of primary water specialists.

Contents

Terminology

The study of terrestrial water, by a growing list of disciplines, has given rise to an ever increasing number of terms for non-aquifer water of unknown or ambiguous origin: primordial water, paleo water, Hadean or Archean water, metamorphic water, telluric water, connate water, magmatic or juvenile water, volcanic water (and vapor) and its oceanic counterpart hydrothermal vents, fissure water, etc. Great effort has been made to distinguish and classify groundwater types through chemical analysis and especially isotope chemistry. Salzman (1960) addressed the then new discipline of Isotope Geology (now Isotope Geochemistry), including:

"Rankama (1956)[32]...sites the findings of many researchers with respect to the variations of specific gravity due to the different amounts of heavy isotopes of both hydrogen and oxygen contained in: atmospheric precipitation; ice; well and spring water; lake water; river water; sea water; connate water, and juvenile water. Briefly the evidence indicates: 1. Atmospheric water vapor is lighter than either fresh water or sea water. 2. The heavier specific gravity differences increase as we go successively from water of ordinary wells and springs to water of mineral springs and then to water of thermal springs. 3. Water in thermal springs have a specific gravity indicative of the admixture of juvenile water and waters of vadose origin. 4. The higher the heavier specific gravity difference the greater the assumption of their deep-seated origin." [33]

While there is almost inevitably some mixing of atmospheric/meteoric water descending from the vadose zone with earth-generated water ascending into the phreatic zone, advances in isotope geochemistry, deep earth seismology and the science of water are leading to the identification and classification—and thus recognition—of the existence of primary water. (See Origin of water on Earth.)

Science

Hydrologic Cycle vs. Primary Water Cycle

The concept that there are two sources of water—telluric and meteoric, deep earth and atmospheric, magmatic and rain-fed aquifer—can be traced to the ancients as well as most religions and creation myths.(See Section on History below.) In more recent times, the development and classification of groundwater has differed widely between Europe, the United States and other countries. In trying to understand the origin of economic minerals Georgius Agricola (born Georg Pawer/Bauer), considered the father of mineralogy, posited in the mid-16th century that certain waters rising from deep in the earth, mostly as vapor (*halitus*in Latin), was the result of the outgassing of the mantle that creates our primary minerals from primary rock.[34] This water was understood to convert predominantly from gas to liquid as it cools upon reaching the fractured crust and then dissipates through fissures, joints and faults where it deposits mineral ores or emerges as both highly mineralized and potable spring waters. In some cases it rapidly reaches the surface via steamingfumaroles and thermal hot springs. It is possible in many areas of the world to have three or four different water sources in close proximity to one another with completely different chemical profiles.

Groundwater hydrology and economic geology, largely driven by German, Austro-Hungarian and Scandinavian universities and scientists (e.g., Alexander Von Humboldt, Karl Vogt, Eduard Suess, Lorand Eotvos, Franz Posepny, Svante Arrhenius, Waldemar Lindgren...), had a great effect on the development of geology, geochemistry and mineralogy in the United States during the late 19th and early 20th centuries.[35] Once the United States Geological Survey (USGS) was launched in 1879 it quickly focused on surveying the vast lands of the American West to map the geology and explore for the raw materials required by industrialization. It was clear that the scarcity of water throughout much of the arid and semi-arid regions would be the crucial factor in settlement and resource exploitation. The USGS organized a series of nationwide groundwater surveys including the cataloging of natural springs led by Oscar Meinzer, considered the father of modern groundwater hydrology. After a career with the USGS Meinzer published in 1942 the book "Hydrology"[36] wherein he espoused that waters of internal origin are tangible additions to the Earth's water supply. Meinzer's work influenced his colleague William Rubey (who would receive the National Medal of Science for leadership in the earth and lunar sciences) to write his seminal 1951 paper, presented as retiring president of the Geological Society of America, with the title "Geologic History of Sea Water"[37] propounding his theory that substantially all the water of the oceans and the atmosphere must have originated from the interior of the Earth. This would mark the high water point in modern hydrology; a decade later William Ackermann, a civil engineer and highly respected hydrologist, would address the American Geophysical Union (AGU) with a paper titled "Needed – Three Wise Men" lamenting the drought in new studies and challenging the AGU hydrologists to expand their research to solve the increasingly complex water problems facing the nation and the world.[38] Ackermann admonished his colleagues by quoting directly from Salzman's book published just months before (emphasis added):

"Most present day hydrologists, whether they work for a governmental agency or as consultants in private practice, whether their initial training has been in civil or hydraulic engineering or in groundwater hydrology, have been ***so thoroughly indoctrinated and inculcated with the methodology and technology based on the applications of the hydrologic cycle theory*** *that, when faced with a water shortage problem for a particular area, they seek a solution only in terms of their training and experience."*

..."It stands to reason, however, that there must be some recognition, by at least some hydrologists, that geochemistry accounts for the addition of some water on the earth and that, therefore, it is a conscious delimiting among some, as well as a mental block among others, that excludes these waters from the science of hydrology."

..."If people in the field of hydrology wish to delimit their science, exclusively to the applications of the hydrologic cycle and hence to the exclusion of the water of internal origin, they may certainly do so. Unfortunately, however, ***government officials, legislators, and the general public are generally unaware of these internal waters and are therefore under the delusion that hydrologists are the water supply experts*** *without realizing that these experts deal with only certain kinds of water, namely the runoff of precipitation or its infiltration in porous rock materials. It is indeed remarkable, as well as incongruous, that those to whom the world looks to for the solution of water shortages can be so disinterested as to relegate the study of the waters of internal origin to other branches of geology."*

..."Despite the fact that hydrologists profess, among themselves at least, of their non-interest in and scant knowledge of the waters of internal origin they nonetheless persist in continuing to delude themselves and the public at large. ***This is accomplished by either a failure to mention the existence of these waters, or by minimizing the amount of such waters, or by deprecating the usefulness or the quality of these waters.****"*

..."The arguments put forth obviate the necessity of a scientific rebuttal. Nonetheless, their position is being presented here in order to expose the type of thinking not only of that of the authors, but common to many people currently engaged in trying to solve the water problems of our country. ***They are loyal, hard working, well meaning and able, but unfortunately their training and work does not leave them with an open mind.****"*

— Michael H. Salzman, New Water for a Thirsty World (1960), p.91-94

Dogmatic resistance persisted for the next half century. While today the Revolution in Water is under way, it is being led not by hydrologists or even hydrogeologists but by seismologists, mineralogists and astrobiologists. The proverbial (hydrological) dam is indeed finally breaking. (See section below on Dogma in the Earth Sciences.)

The Earth's Deep Water Cycle

In 2006 a seminal paper was published by the very same American Geophysical Union describing the Earth's Deep Water Cycle as a result of the interdisciplinary work in mineralogy, geophysics, geochemistry, and led by seismology which involved experimental, modeling, and seismic studies.[39] Northwestern University professor Dr. Steven Jacobsen, who for many years had developed deep-earth seismology in parallel with advancements in technology and computer science, for the first time clearly defined the existence of a massive hydrous zone in the transition zone from the inner to the outer mantle. Since it is not possible to observe the Earth at depths of hundreds of kilometers (the Kola Superdeep Borehole reached over 12,000 meters, less than 8 miles) it would take a team led by a geochemist, University of Alberta professor Dr. Graham Pearson, to find physical proof of this hydrous transition zone through rock and mineral evidence. This dramatic discovery was announced with great publicity on March 12, 2014.[40,41,42,43,44,45,46,47] A deep earth diamond ejected to the surface after traveling through the transition zone of the mantle, and collected during field surveys in Brazil, was determined in a Canadian laboratory to have an inclusion of ringwoodite, an olivine mineral that contains some 2% water (actually hydroxide ions: hydrogen and oxygen atoms forming an anion, OH^-).

Scientists have forced back into the open discussion of competing theories that can be traced to ancient times. The leading interdisciplinary scientific journal Nature admitted (emphasis added), "There are two theories as to where the mantle's water came from. One is that it was ocean water that was carried deep underground when sea-floor rocks were subducted by plate tectonics. The other is that **deeper layers of the Earth still contain water that was part of the materials that formed the Earth**."[48] And LiveScience followed up (emphasis added): "The diamond from Brazil confirms that the models are correct: Olivine is ringwoodite at this depth, a layer called the mantle transition zone. And **it resolves a long-running debate about water in the mantle transition zone.** The ringwoodite is 1.5 percent water, present not as a liquid but as hydroxide ions (oxygen and hydrogen atoms bound together). The results suggest there could be a vast store of water in the mantle transition zone, which stretches from 250 to 410 miles (410 to 660 km) deep. 'It translates into a very, very large mass of water, approaching the sort of mass of water that's present in all the world's ocean,' Pearson told Live Science's Our Amazing Planet."[42]

These discoveries have far-reaching implications for the Earth Sciences. Another group of scientists, from the rapidly emerging field of astro-biology, is making parallel discoveries of Earth's earliest water captured in Archean formations, the oldest of the accessible rocks at the surface of the crust.[49] This science is based largely on isotope chemistry which has its roots in the work of Harold Urey, recipient of the Nobel Prize in 1934 for his discovery of deuterium, who in a 1952 paper would postulate, "Both water and metallic iron are important constituents of earth."[50] Analysis of both hydrogen isotopes (leading to the discovery of deuterium and tritium) and oxygen isotopes and their ratios led to greater interest in the role of water in the formation of planets and the Universe. As fate would have it, many of the greatest scientific minds would be pulled into the post-World War II atomic programs and the Space Race, further contributing to the neglect of the earth sciences. The downsizing of NASA in recent years combined with the advancements in biochemistry has, auspiciously, led to increased research by astro-biologists in the traditional domain of the earth sciences. University of Hawaii - NASA Astrobiology Institute researcher Dr. Lydia Hallis's isotope studies of archaean rock on Baffin Island and Icelandic lavas led to the conclusion, "Such strongly negative values indicate the existence of a component within Earth's interior that inherited its D/H (deuterium: protium) ratio directly from the protosolar nebula."[51] Geo-hydrology has come full circle in just 55 years! Recognition of the existence, regardless of its exact origin, of the Earth's Deep Water Cycle—or, to use the classical terminology, the Primary Water Cycle—can now lead to further analysis and quantification of the Earth's groundwater resources and their sustainable exploitation to bring an end to the cries of Peak Water.

The Revolution in Oil (& Gas) and the Revolution in Water

"At no time is water static. It is constantly changing form. It is either a liquid or gas, or it is bound up in crystalline form in rocks and minerals. The cycle of gas to liquid to crystal is repeated over and over. Oxygen and hydrogen combine under the electromechanical forces of the earth to form liquid water. Not only is water being constantly formed within the earth, but also rocks, minerals, and oil. What I seek is water in its liquid state."

— *Stephen Riess, 1954*

The concept of primary water is closely related to the theory of abiogenic (or abiotic) oil and gas. The modern theory of fossil fuels is generally attributed to Mikhail Lomonosov in 1757. But it would be challenged by such eminent geologists as Alexander von Humboldt and, in this century, by the so-called Russian-Ukrainian school, first enunciated by Nikolai Alexandrovich Kudryavtsev in 1951,[52] and their American ally former professor and oil exploration geologist Dr. Jack Kenney (Ph.D. from M.I.T.).[53]

The basis of Peak Oil theories is that fossil fuels by definition are finite and that global exploration of petroleum deposits peaked by the end of the 20th century and that over-production would result in increased resource scarcity. As often occurs, such predictions have proven premature. Three elements came together in 2005 that would lead to the (still poorly understood) Revolution in Oil—within a decade ending the cries of Peak Oil and changing global energy strategies and related geopolitics since the formation of OPEC. The science of "unconventional oil" combined with horizontal and directional drilling has allowed for exploration and production (E&P) companies to develop previously overlooked formations. But to fully capitalize on these trends required wholesale change in mineral leasing laws and regulations. This regulatory change occurred with the passing of the Energy Policy Act of 2005 and related rule writing at the Minerals Management Service of the Department of the Interior. Within a decade the United States would be referred to as "the Saudi Arabia of oil" and in 2016 U.S. reserves would surpass those of Russia and Saudi Arabia.[54] And the related production of natural gas appears set to dwarf crude oil production.[55]

These developments have a direct correlation with the nascent Revolution in Water and in other natural resources, such as helium (emphasis added): "A **new approach to gas exploration** has discovered a huge helium gas field, which could address the increasingly critical shortage of this vital yet rare element.[56] Old theories related to outgassing of the Earth, abiotic mineral origins (with the increasing use of the term "pre-biotic"), and planetary expansion are being revived and entering the mainstream as the evidence becomes overwhelming that the "established science" of the post-World War II period is breaking down.

The Revolution in Water is occurring both in laboratories—as described in great detail by Dr. Gerald Pollack in his groundbreaking work "The Fourth Phase of Water" and the work of the international Water Conference which he now heads[57]—as well as in the applied science of geo-hydrology and related earth sciences disciplines. A similar concept of "unconventional" aquifers is now being explored as various disciplines investigate the potential of renewable non-aquifer sources of groundwater.[58] Left almost entirely out of academic textbooks, nevertheless a recent high school supplement, Encyclopedia of Earth and Space Science, when reviewing the issue of water in the Arab-Israeli conflict, dares students to challenge the status quo (emphasis added):[59]

"One possible way to alleviate the drought and water shortage would be to explore for water in ***unconventional aquifer systems such as fractures or faults****, which are plentiful in the region. Many faults are porous and permeable structures that are several tens of meters wide, and thousands of meters long and deep. They may be thought of as* ***vertical aquifers, holding as much water as conventional aquifers****. If these countries were to be successful in exploring for and exploiting water in these structures, the water shortage and regional tensions might be reduced. This technique has* ***proven effective in many other places in the Middle East, Africa, and elsewhere****, and would probably work here as well."*

— *Encyclopedia of Earth and Space Science, 2010*

Dogma in the Earth Sciences

"The inertia of the human mind and its resistance to innovation are most clearly demonstrated not, as one might expect, by the ignorant mass--which is easily swayed once its imagination is caught--

but by professionals with a vested interest in tradition and in the monopoly of learning. Innovation is a twofold threat to academic mediocrities: it endangers their oracular authority, and it evokes the deeper fear that their whole, laboriously constructed intellectual edifice might collapse. The academic backwoodsmen have been the curse of genius from Aristarchus to Darwin and Freud; they stretch, a solid and hostile phalanx of pedantic mediocrities, across the centuries."

— *Arthur Koestler, The Sleepwalkers (1959), p. 427*

Many have written on the dogma in Science, some pointing to the corruption engendered by government or private funding and others to institutional atrophy and individual egotism. Specific to groundwater resource paradigms, the cases of primary water and fractured rock aquifers are most telling. By the late 1950s California was suffering another extended drought and once again the politicians looked to the system of dams and water diversion by long-distance aqueducts to solve the problem, as had been done from the Owens River Valley and the Colorado River during previous crises. Yet by the late 1950s the work of Stephen Riess was well-documented and private interests sought to present drilling a system of back-up primary water wells for use in just such times of water scarcity. The U.S. Senate Select Committee on Water Resources held hearings for two years, including in Los Angeles where Riess was invited to present. Great effort was taken to prevent the "rock drillers" from competing with the job creation scheme of the Feather River Project favored by then Governor Pat Brown, the bankers who would benefit from the multi-billion dollar bonds, and the large farmers of the Central Valley who would receive highly subsidized water. This was the backdrop when Michael Salzman researched the theory of earth-generated primary water and wrote "New Water for a Thirsty World" in 1960. No sooner had it been published than most copies were bought up and destroyed by supporters of the $1.5 billion California Aqueduct referendum which would pass later that year—and after over $4.5 billion still not be completed. Now, some 50 years later, and after four more droughts, California in 2014 passed a new $7.5 billion water bond[60] with Governor Jerry Brown (yes, Governor Pat Brown's son) lobbying for yet another surface water diversion scheme.

During those politically charged times, a 1958 study conducted by hydrologic engineer O.R. Angelillo, assisted by Riess, resulted in the mapping of an extensive "rock fissure aquifer" system draining into the Mojave Desert.[61,62] Their work was funded by Los Angeles developer Nathan Mendelsohn and led to the founding of California City.[63,64,65,66] Over half a century later those Riess wells still provide 70% of the city's municipal water supply. But the concept of fissure or fractured rock aquifer would be further developed by others. Starting with the successful development of new water resources in the granite formations of southern New Hampshire, a team of geologists, hydrologists and geophysicists would, by 1989 and after work in Somalia and the Sudan for USAID, publish a paper on the most dramatic new concept in modern hydrology: Megawatersheds.[67] They would go on to solve critical water shortage challenges on Tobago and then Trinidad in 2000-2002 after which they published the groundbreaking book, "Modern Groundwater Exploration: Discovering

New Water Resources in Consolidated Rocks Using Innovative Hydrogeologic Concepts, Exploration, Drilling, Aquifer Testing, and Management Methods" (2004) against great resistance:[68]

“If megawatershed technology offers so much promise, why has it not been more widely accepted? As the man said, "if this is so important, why is it not happening?" The first barrier is outright skepticism blended with a fair dose of vested interest in the status quo. ...A major challenge faced by the proponents of the megawatershed theory is to overcome the resistance in the professional water community.”

— *Alexander Raymond Love, Megawatersheds - A New Paradigm (2004)*

Frequently Asked Questions (FAQ)

Q. *Why haven't we heard of "primary water" before?*

A. Primary water is not a new concept; science has long considered and investigated earth-generated water, most often referred to as juvenile or magmatic water in the literature and more recently as primordial or paleo water. (See Terminology section above.) Just think of the steam produced by a volcano and associated thermals, hot springs and high quality mineral waters, as well as the mountain sources of creeks, streams and rivers—there is certainly water emerging from within our planet.

The reason you have not heard about primary water has more to do with popular scientific theories about origin of water on Earth—such as comets and asteroids—and with our focus on the water system we see and are most familiar with: the hydrologic cycle of water that includes runoff, evaporation and precipitation. Much less attention has been paid to the water that comes from far beneath our feet.

Our lack of understanding about primary water has led to massive reservoir and dam construction as we have made great efforts to store and transport water, often long distances, on the surface of the earth—yet right below us has been a renewable, sustainable, non-aquifer water source ready to be tapped and used by humans, animals, farms and industry.

Q. *How do you know that it’s not just aquifer water?*

A. Earth-generated primary water will often be chemically distinct from nearby aquifer wells, and when drilled, cased and completed properly are free of bacteria and contamination from the surface. Global Resource Alliance[69,70,71] (GRA) of Ojai, California has now drilled more than 100 wells in the arid Mara region of Tanzania where no aquifer is deemed to exist in the volcanic formations of the Rift Valley. The GRA wells have an average depth of 200 feet and are free of bacteria, unlike all others in the district; the water rises under pressure, resulting in a near surface static level so that a simple submersible or even mechanical pump can bring this high quality water to the surface. The water in all cases is potable directly from the well, without need for filtration. The savings are enormous when compared to typical deep aquifer wells with expensive pumps and chemical filtration systems.

Q. *Is this water ever a blend of primary sources and aquifers?*

A. A range of technologies exist to assist in locating primary water sources in all geologic formations, regardless of soil or precipitation. Regarding the mixing of earth-generated and atmospheric water, primary water, now more than ever considered to be the original source of our atmospheric water (see Section on Science below), does mix in the vadose (near surface) and phreatic (aquifer) zones where rainwater percolates and collects. However, in many formations, earth-generated water can reach near or to the surface without mixing or contamination, usually when contained and channeled in fissures or fractured rock formations. For this reason, care must be taken when drilling to seal off atmospheric sources and minimize mixing and surface contamination.

Q. *How do you locate and access primary water?*

A. Unlike traditional water well drilling that seeks rainwater collected in aquifer basins and "tubs," primary water precision drilling seeks fractures and fissures of the earth to release trapped earth-generated water, often originating as steam at great depth which converts to liquid water as it cools in the crust and reaches the surface under pressure. Geo-hydrologists use a standard rotary air hammer rig with a strong compressor and almost always drill into bedrock, thus nicknamed "rock drillers". A dual rotary (DR) drilling rig is preferred because it sets the well casing to considerable depth at the same time it drills the borehole and thereby seals off contamination.

This is not fracking. Primary water pinpoint-locating and precision-drilling have very minimal environmental impact. Thousands of water wells are drilled around the world every day, and some 800,000 per year are drilled in the United States alone. Most are small-bore residential wells with mainly agricultural production wells preferring 12" diameter and larger. Primary water well drilling uses no chemicals, minimal mud or bentonite and preferably 100% air in order to avoid contaminating the well while drilling—often allowing for open-bore shafts in solid rock.

Q. *Why hasn't it been done before?*

A. It has been. (See Section on History below.) Not including the many natural springs and wells in use for thousands of years, primary water sources are being located and utilized worldwide, usually locally and without fanfare. In 2013 in Ngu Nyumu, Kenya, primary water geo-hydrologist Pal Pauer located a well, funded by the Rotary Club of Santa Barbara North and Friends of Woni - Kenya International, in a region experiencing water shortages, that continues to supply water to over 1500 people.[72,73] They refer to it as the "magical well" because many efforts by government geologists to find water there were unsuccessful, and the location chosen by Pauer was "unconventional" and required drilling into hard rock almost directly on the surface.

In the US, primary water pioneer Stephan Riess located and drilled hundreds of wells, including a dozen wells that over 60 years later still provide 75% of the water for California City in the middle of the Mojave Desert. His statement to a U.S. Senate Select Committee on National Water Resources in 1959 highlights his many successes worldwide in finding "rock fissure" or primary water, and he also refers to many accidental discoveries of primary water, including one in Manhattan in 1956 that produced over 2000 gallons per minute and over 1 billion gallons of water in a 13-month period. This water was tested extensively to determine its source, and chemists certified that the water was not from the (then very contaminated) Hudson River, but was pure and fit for human consumption without filtration. Unable to determine the source of the water, officials considered the matter closed when the accidental spring was sealed off with the construction of the 12-story building and parking lot on top of the source.

Q. *Can you drink it straight from the well?*

A. Primary water makes its way from deep in the Earth to the surface in the vapor via volcanoes and fumaroles and thousands of hydrothermal vents on the ocean floors, as well as through highly mineralized geysers, thermal springs, and mineral springs. It also produces most of our purest natural spring water extracted, bottled and sold by commercial water companies around the world. The Food and Drug Administration reduced the bottled water total dissolved solids (TDS) limit from 1000 to 500 parts per million (ppm), while allowing for the "mineral water" category to exceed 500 ppm. This means that most primary water wells can be consumed directly at the source or bottled with minimal treatment as spring water or mineral water. However, in some formations a TDS of even 4000 ppm or more can produce mineral-rich yet perfectly pH-balanced water that provides crops and orchards with both high quality earth-generated water and natural fertilizer. Thermal hot springs, often highly mineralized, have been sought out—often purposefully located and drilled into—and protected worldwide for their re-energizing and healing effects.

History

Ancient Rock Drillers

Across the arid Middle East and Asia there developed extensive systems of well drilling through rock and water channels often for long distances underground: *qanat* in Iran, Baluchistan and Afghanistan; *karez* in Jordan, Kurdistan, Azerbaijan, Armenia and northwestern China; *falaj*/*aflaj* in Oman; *foggara*/*fughara* in North Africa.[74] It is well documented that many of the source wells of these systems were dug through solid rock to reach water sources that would often rise under pressure and then be transported to lower elevations for use in villages and farms. Many Hellenistic and Roman aqueduct systems appear to have been based on the same concepts.[75]

“Once a falaj system starts running, it never dries up, no matter how hot or dry the weather, because massive aquifers in rocky layers fed by rainwater constantly feed the falaj. Of the 4,112 known aflaj in Oman, 3,017 continue to deliver water to villages and fields.”

— *"Sustainably Tapping Groundwater", The Falaj System, at Biosphere 2 in Oracle, AZ, USA*

The signboard does not explain how so many wells could produce such a continuous and thus renewable water source in a desert region. That the earliest civilizations understood earth-generated primary water, how to locate and develop it, is quite evident to those who have studied such ancient systems in arid regions. Both the Crusaders (e.g., Kerak) and Saladin (Ajloun) built castles and fortresses at the top of mountains where they excavated shafts great distances through rock to intersect high quality flowing veins of water.

Religious Concepts of Groundwater

From the very first verse of the Hebrew Bible the "two waters" (Hebrew *mayim* (מָ֫יִם), which is a dual form) are mentioned, and eight times in the first ten verses of Genesis. The Qur'an similarly speaks of two waters (25:53): "And it is He Who has let free the two seas, one palatable and sweet, and the other salt and bitter, and He has set a barrier and a complete partition between them." And further presages the concept of fractured rock aquifers (2:74): "...And indeed, there are stones out of which rivers gush forth, and indeed, there are of them which split asunder so that water flows from them..." Both the Bible and Qur'an recount the story of Moses striking stone with his staff to bring forth the 12 wells that would sustain the tribes of Israel. Jacob's Well in Nablus and the Well of Zamzam in Mecca have continuously produced high quality water for millennia.

Early Theories of Groundwater

While Thales taught that water was the source of all things, Anaxagoras (c. 500-428 B.C.) as discussed by Aristotle, and later by Hippolytus in the late second century C.E.,[76] claimed that oceans were created from two sources: rivers flowing into the seas and "water of the earth" upon which even the rivers largely depended (emphasis added):

“Now we turn to the liquids on the earth: The sea existed all along, but the water in it became the way it is because it suffered evaporation, and it is also added to from the rivers which flow into it. ***Rivers originate from rains and also from subterranean water****...”*

— *Hippolytus (on Anaxagoras), A Refutation of All Heresies, c. 200 C.E.*

Both Plato and Aristotle, as described in the latter's treatise *Meteorologica*, believed that water was formed within the Earth as well as in its atmosphere as a result of the observation that clouds formed more often near the surface and less in the high atmosphere thus reflecting the exhalation caused by fire changing internal and external waters to vapor.[77]

Vitruvius, writing between 24-17 B.C.E., might be considered both the first hydrologist, for identifying the hydrologic cycle concept of evaporation and rainwater percolating through soils, and also the first geo-hydrologist as he extensively described methods to locate water veins and noting the correlation between high quality water and certain rock formations.[78] In the first century C.E. it was Pliny the Elder who further described, in his early encyclopedia Natural History, water flowing in veins that "pervaded the whole earth within and ran in all directions bursting out even on the highest ridges."[79]

Renaissance in Groundwater

All of these themes would be taken up by Leonardo da Vinci, in his many drawings of and writings on water, elaborated in his Treatise on Water using terms familiar to plate tectonics and the more controversial Expanding Earth Theory (now fully developed into the science of expansion tectonics[80]):

"So when we say that the earth has a spirit of growth, and that its flesh is the soil; its bones are the successive strata of the rocks which form the mountains; its cartilage is the tufa stone; its blood the veins of its waters. The lake of the blood that lies around the heart is the ocean. Its breathing is by the increase and decrease of the blood in its pulses, and even so in the earth is the ebb and flow of the sea. And the vital heat of the world is fire which is spread throughout the earth; and the dwelling place of its spirit of growth in the fires, which in divers parts of the earth are breathed out in baths and sulphur mines, and in Vulcanus and Mongibello in Sicily, and in many other places."[81]

— *Leonardo da Vinci, Treatise on Water*

Georgius Agricola, mentioned above, is credited as the father of mineralogy whose work led directly to the development of economic ores in Germany, France and England so critical to the coming Industrial Revolution. None other than future American president and international mining engineer Herbert Hoover and his wife Lou Henry Hoover would be the first to translate Agricola's most famous work De Re Metallica (1556) into English. And in a lengthy footnote, they would describe Agricola's theory which clearly foreshadows the Earth's deep/primary water cycle:[82]

"Origin of Ground Waters. (De Ortu p. 5). "...Besides rain there is another kind of water by which the interior of the earth is soaked, so that being heated it can continually give off *halitus*, from which arises a great and abundant force of waters." In description of the *modus operandi* of *halitum*, he says (p. 6): "...*Halitus* rises to the upper part of the *canales*, where the congealing cold turns it into water, which by its gravity and weight again runs down to the lowest parts and increases the flow of water if there is any. If any finds its way through a *canales diletata* the same thing happens, but it is carried a long way from its place of origin."

— *Georgius Agricola, De ortu et causis subterraneorum (1544)*

Bernard Palissy, largely forgotten, would revive Vitruvius's theories in 1580.[83] In the following decades Johannes Keplerand Rene Descartes would further develop modern hydrologic theories, both positing that water recycled from the deep ocean's led to natural springs. And between the 1600s and 1700s the modern concepts of hydrology, based heavily on hydraulic engineering, emerged.[84]

Modern Concepts of Groundwater

While modern hydrology would move towards hydraulics and civil engineering, the geo-sciences matured into the fields of geology, mineralogy, geo-chemistry and geo-physics as nearly every corner of the globe was discovered, explored and mapped. Eduard Suess might be considered the founder of modern geo-hydrology as a result of his selection to solve the water quality problems of Vienna in the 1850s when the city suffered a high incidence of typhoid. His proposal, selected from among many, was to develop spring water wells high above the city and use gravity flow to the population. It was during this time, and after his study of the Carlsbad (now Karlovy Vary) thermal springs, that he formulated the concepts of juvenile water and its occurrence often in the mountains and at higher elevations, rising under great pressure related to volcanism. He would later write extensively on the concept:[85]

“Volcanological studies led Suess to posit that oceanic waters result from the degasification of the earth (III , pt. 2, 631). He introduced the distinction between juvenile and vadose waters (III , pt. 2, p. 630). Juvenile gases and, higher in the earth’s crust, thermal waters not only displace and concentrate numerous chemical elements: they are also important in the transport of terrestrial heat. Juvenile gases, Suess thought, originate under the sialic crust, a term created to indicate that silicon and aluminum are the principal and characteristic elements of this terrestrial layer (III , pt. 2, 626). Under this first sphere would be that of sima (characterized by silicon and magnesium) and finally the barysphere or nife (nickel and iron), which is primarily metallic. Studies of abyssal rocks sometimes suggested the presence of a “crofesima” or “nicrofesima”(III, pt. 2, 627). Suess thought that juvenile gases also played a role in lunar volcanism (III, pt. 2, 689).”

— *Encyclopedia.com*[86]

In the United States, the concept of juvenile water would be picked up by such acclaimed figures as Frank Wigglesworth Clarke, considered the founder of modern geochemistry, and Josiah Edward Spurr, a pre-eminent American geologist, explorer and prolific writer for half a century. Clarke, in his USGS bulletin "The data of Geochemistry" (1920) applied chemical analysis to a wide range of terrestrial and oceanic waters, and included an almost encyclopedic classification of waters in his chapter on Mineral Wells and Springs culminating in sections on "Vadose and Juvenile Waters" and "Thermal Springs and Volcanism" (emphasis added):[87]

"The subdivision of springs into vadose, or those which represent original infiltration of surface waters, and juvenile, as Suess terms them, has had wide but not universal acceptance. A difficulty in applying the nomenclature arises from the fact that it is not easy to determine where a given water belongs. ...Virgin or juvenile waters, on the contrary, are fairly constant in all essential particulars... ***The vadose water, moreover, issue from faults having no relation to the metallic veins of the surrounding territory--a lack of relation which is conspicuous as regards juvenile springs.*** *...When a crystalline rock, like granite, is heated to redness in vacuo, water and gases, the latter identical in character with the volcanic gases, are given off. For instance, to cite the least significant example, 1 cubic kilometer of granite can yield from 25 to 30 million of metric tons of water, which at 1,100° would form 160,000,000,000 cubic meters of steam."*

— *Frank Wigglesworth Clarke, The data of Geochemistry (1920)*

A few years later Spurr would take up the subject in his textbook on the application of geology to mining and metallurgy (emphasis added):[88]

The water which is given off at the contact of an intrusive mass of igneous rock, and which is frequently so active in producing rock changes or metamorphism, must also exist after it has accomplished these changes. We may suppose that if there are any channels, such as are afforded by fissures or faults, this water may find its way upward, and perhaps even reach the surface.*Springs having this origin may be called (following Professor Suess of Vienna) juvenile springs, the term referring to the recent birth of the water from the magma.*

— *Josiah Edward Spurr, Geology applied to mining (1926)*

Theory of Primary Water

As mentioned in the introduction, the term primary water in the modern period dates to the study and resulting paper by Adolf Erik Nordenskiold describing the 33 boreholes he drilled in the hard rock of Scandinavia:[89]

"It appears that everywhere that one drills in the primary rocks in Sweden and Finland, at a constant depth of a little over 30m under the surface of the earth, a water bearing horizontal fissure is encountered. The theories about folding and the displacement of the primary rocks' surface layers by temperature variation have been clearly corroborated hereby… It comes free from the bacteria that exist in the earth's surface layers, from organic detritus, from decay produced and other things injurious to health and for our purposes it is unexcelled in hygienic respects, having a temperature transcending a little the average temperature at the place where the wells were drilled."

— *A.E. Nordenskiold, About drilling for water in primary rocks (1896)*

Nordenskiold's inquiry was precipitated by his father, Nils Gustav Nordenskiöld, a prominent Finnish geologist, explorer and member of the Russian Academy of Sciences, who observed the existence of high quality potable water emerging from mines even when surrounded by salt water on promontories and rocky islands around Scandinavia. Independently of the Nordenskiold's, the German-educated mining engineer and geochemist Stephen Riess would make the same discovery while working for the Hoover family in gold mines in the American Southwest. Riess drilled his first purposefully sited primary water well in El Dorado Canyon south of Las Vegas, where the mines used river water pumped great distance and at high cost from the Colorado River. At a depth of less than 200 feet he struck a water source that rose so rapidly under pressure that the workers barely escaped, causing a large lagoon to develop until the water was brought under control. The well would remain in use for 40 years; it now sits abandoned, surrounded by barbed wire.

Riess would go on to document over 800 primary wells he located and drilled from 1934 to 1985 in California, Nevada, Arizona, Oregon and Idaho, as well as in Israel, Egypt, Saudi Arabia, Cyprus, Mexico and Brazil. Many of these projects are recounted in Salzman's book[90] and in the many articles referenced in the introduction to this article. The Riess Institute was founded in the 1970s to identify the dynamics of "new water" generation deep within the Earth's interior. Riess disciple and fellow geo-hydrologist Pal Pauer has spent over 50 years locating high quality primary water in the American Southwest, helping launch the Global Resource Alliance program in Tanzania (now over 100 wells in the arid Mara region), and documenting projects in Kenya, Mexico and the Philippines. Pauer founded The Primary Water Institute in 2014 to carry on the work of Riess and The Riess Institute.

Dowsing and Primary Water

Dowsing—or water diving or water witching (or doodlebugging, usually in reference to locating oil)--is a well-documented and ancient practice.[91,92,93] There were numerous attempts during the 20th century to prove the science behind the practice. Most notable was the career of Verne Cameron whose ideas, many projects and Theory of Primary Water were documented by his disciple Bill Cox.[94] Cameron located wells throughout California and the Southwest, both thermal and potable, still in production 50 years later without correlation to rainfall or drought. Cox would locate many primary water wells over 35 years for government agencies, industry and agricultural clients worldwide, including in Japan where he lectured on the subject.[95] Both Cameron and Cox drilled the source wells that would refill the dry lake bed of Lake Elsinore in Riverside County, California.[96] These wells would be refurbished in 2004 and produce over one billion gallons per year, half a century later, to stabilize that lake.[97,98]

The German Society for Technical Cooperation (formerly the GTZ, now the GIZ), funded a decade-long study of dowsing "Unconventional Water Detection" published in two parts.[99,100] In the abstract to Part 2, Betz makes the following statement (emphasis added):

“This report presents new insights into ***an unconventional option of locating water reserves*** *which relies on water dowsing. The effectiveness of this method is still rightly disputed. Now, however, extensive field studies - in line with provable and reliable historic accounts - have shown that* ***a few carefully selected dowsers are certainly able to detect faults, fissures and fractures with relative alacrity and surprising accuracy in areas with, say, crystalline or limestone bedrock****. A series of Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) projects involving this technique were carried out in dry zones with unexpectedly high rates of success. In particular, it was possible to locate a large number of relatively small underground aquifers in thinly populated areas and to drill wells at the sites where water is needed; the yields were low but sufficient for hand-pump operation throughout the year.* ***Finding or locating a sufficient number of relatively small fracture zones using conventional techniques would have required a far greater work input.****”*

— *Hans-Dieter Betz, Unconventional Water Detection (1995)*

While the "science of dowsing" may forever be disputed, no applied scientist can disregard the documented ability of innumerable dowsers, in nearly every region of the world, to pinpoint locate high quality water where traditional hydrologists and hydrogeologists declare it is not to be found. One only has to conduct an Internet search to learn of the widespread use, not just by farmers but also municipalities and private water companies, of experienced dowsers and water diviners during the current drought in California.[101,102,103,104,105]

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