SO MUCH TO LEARN:

Dye Tracing the Current River Landscape, Part III

by QUINTA SCOTT

Welch Spring: Halbrook Branch of Upper Gladden Creek-Meramec Headwaters

It rained hard a few days before Anne Keller injected dye into the Halbrook Branch of Upper Gladden Creek in the Meramec headwaters. She estimated that it was running at about 75 gallons per minute over a low water bridge in Dent County. A half-mile downstream of her injection point, the stream dried out and remained dry for several miles. She recovered her packets from Welch Spring with positive results.[1]

Tuesday November 10, 1818: *It was the edge of a prairie where we had halted. Wood was rather scarce; but we made shift to build a good fire.*

Wednesday November 11, 1818: *In passing two miles, we crossed a small stream running south-east, which evidently had its source in the little lake at our last night's encampment. The trail beyond this was often faint; in the course of eight or ten miles, we began to ascend elevations covered with pines, but of so sterile and hard a soil that we lost all trace of it. We wound about among those desolate pine ridges a mile or two, till, from one of the higher points, we descried a river in a deep valley, having a dense forest of hard wood, and every indication of animal life. Overjoyed at this, we mended our pace, and, by dint of great caution, led our pack-horse into it. It proved to be the river Currents, a fine stream, with fertile banks, and clear sparkling waters.*

– HENRY ROWE SCHOOLCRAFT, 1818[2]

Henry Rowe Schoolcraft described the progression of landscapes in the eastern Current River watershed in the journal he kept as he explored the Ozarks in 1818 and 1819. He began his tour in Potosi; traveled south through the Cortois and Huzzah valleys; crossed the West Fork of the Black River to the headwater streams of the Meramec; crossed upland savannas pockmarked by little lakes (sinkholes); entered the forested lands that clothe the valleys of Current River tributaries; and descended through their sheer valleys to the river itself. He crossed the river just south of Montauk Spring. Schoolcraft described the Current River landscape of 1818 in much the same way the Missouri Department of Conservation (MDC) would describe it in 2002 when it published its *Atlas of Missouri Ecoregions* and defined it as the Current River Hills ecoregion.

Millions of years ago the Ozarks region was a peneplain, a relatively flat plateau, across which the rivers the Meramec, the Current, the Gasconade, and others meandered. At least 320,000,000 years ago, maybe more recently, a slow uplift pushed up the plain. The rivers responded by cutting deep valleys, maintaining their meanders and leaving behind remnants of the peneplain—Schoolcraft's prairies—on ridges between watersheds. All are relatively level plains, where local relief is seldom more than 100 feet. Sinkholes litter all. Some deliver water to underground systems. Major tributaries to the Current, Big and Spring Valley creeks, which are also losing streams, head at the barren (prairie) edge and deliver water to springs. In Schoolcraft's time, stubby post oaks grew on fragipan, poorly drained soils on the ridges. Today, we find cattle grazing on fescue pastures. The MDC named such landscapes Oak Savanna/Woodland Plains.

On the process of **selecting a dye injection site:**

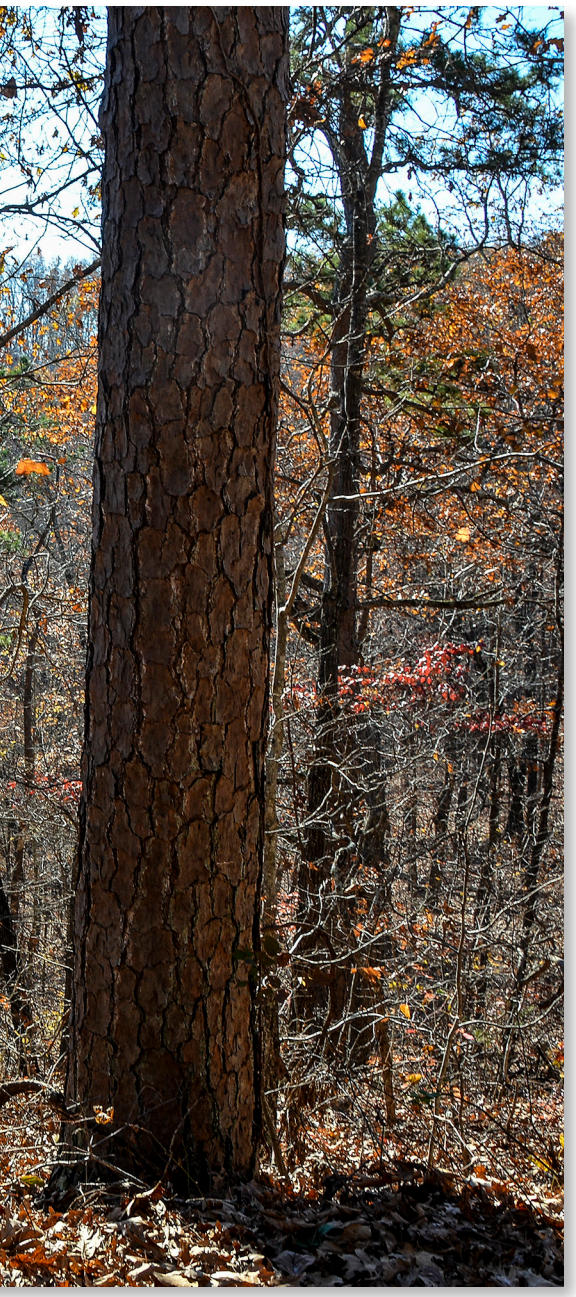
"It is based on lots of field work and lots of walking the hollows of the Ozarks. *It is a combination of art and science, and an ability to understand the land and how it functions."*

The MDC described Schoolcraft's "desolate pine ridges" as the Oak-Pine Woodland/Forest Hills, where the soil is cherty. Historically, a woodland mix of oaks and pines covered the rolling hills, where the landscape rises and falls as much as 250 feet. At the end of the nineteenth century, loggers moved in and stripped the woodlands. Today, dense second-growth oak and or oak-pine forests dominate the hills.

As he approached the Current River, Schoolcraft crossed narrow, rugged ridges that dropped down as much as 500 feet along steep slopes, anchored by oaks, into the fertile Current River Valley. The MDC named this region the Current River Oak Forest Breaks. Unlike the oak/pine woodland,

Schoolcraft's "desolate pine ridges"

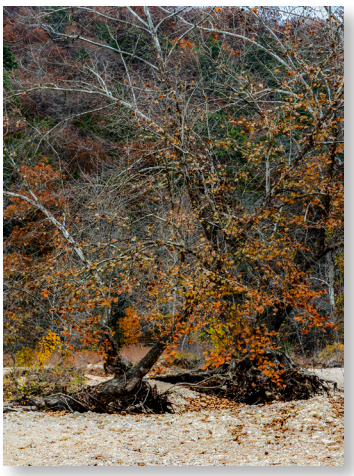
the forested breaks remain intact. Hardwoods covered the river floodplain, which is lined in tall bluffs. Huge springs, which draw water from all parts of the watershed, feed a steady stream of water to the river.[3]



This is the last of a three-part series on our undetstanding of the Ozark National Scenic Riverways in the Current River watershed since 1964. The first covered the establishment of the Ozark National Scenic Riverways and our early forays into understanding its watershed. Research began in 1912 when Thomas Jacob Rodhouse measured the flow of the Current above and below Big Spring and continues to this day. Between 1968 and 1973, Thomas Aley conducted his study of the Hurricane Creek watershed and delineated the extent of the Big Spring Recharge area. The creek, a classic losing stream and a tributary of the Eleven Point River, delivers water through subterranean channels that run under the drainage divide between the Eleven Point and the Current to Big Spring, a tributary to the Current River. Aley's conclusions focused on the interplay between land use on the surface and groundwater quality.[4]

The second part discussed the Doe Run applications to mine lead in the Hurricane Creek watershed and the explosion of research that followed. It focused on the efforts of the U.S. Geological Survey to map the karst landscape of the Current River watershed between 1995 and 2001. The project provided a geological inventory of the Ozark National Scenic Riverways. The Missouri Department of Conservation sorted out the progression of landscapes in the watershed, catalogued it its *Atlas for Missouri's Ecoregions*, and published maps in 2002.

The third part explores Current River country, its prairies, its losing tributaries, and its springs. Again, Thomas Aley's work guides us through the landscape. In 1973 Aley completed the Hurricane Creek project, opened his Ozark Underground Laboratory at Protem, Missouri, and began working as a consultant on hydrogeology, caves, and the management of karst regions. One of his first clients was the Ozark National Scenic Riverways, for whom he delineated the recharge areas of the springs that feed the Current River.



Sunklands Conservation Area: McHenry Hollow

Tom Aley described the process of selecting a dye injection site: "It is based on lots of field work and lots of walking the hollows of the Ozarks. It is a combination of art and science, and an ability to understand the land and how it functions. Losing stream segments are often ideal locations. They are best when most or all of the flow of the stream is sinking in a very localized area. This often means that you need to be there during or shortly after rainstorms. You

"No Dumping."

so said a **sign at the sinkhole.**

don't always guess right and may get to a point you have selected only to find that conditions are not suitable.

"You also need dye introduction points that will give you as much useful information as possible. If you are concerned with protecting water quality, then a site downstream of a source of contaminated water is routinely more useful than a site way out in the woods somewhere. A site near the potential boundary between a couple of recharge areas is more useful than a site where it is pretty obvious where the water is likely to go."[5]

Montauk and Welch Springs: Bean Creek Injection Site

In 1972 soon after the dedication of the Ozark National Scenic Riverways in 1971, the National Park Service embarked on a series of studies on management of the new park, including a groundwater study of the Current River watershed. Aley's earlier Hurricane Creek study for the U.S. Forest Service prompted the fifteen-year effort to delineate the recharge areas of the major springs on the Current River. He worked from his Ozark Underground Laboratory in Protem. His first client was the University of Missouri-Rolla, where he worked on Round Spring with James Maxwell, a geologist with the Water Resources Research Center at the university.

With his work with Maxwell finished, he began performing contract work for the Ozark National Scenic Riverways on a regular basis. Between 1975 and 1976 he delineated the recharge areas of Alley, Round, and Pulltite springs and assessed areas that are hazardous to the water quality of each spring. In a second contract in 1977 and 1978 he delineated the recharge areas of springs north of the Jacks Fork and west of the Current. In 1982 Aley crossed the Current and began tracing the sources of springs in its eastern watershed and north of U.S. 60. By the time he and Catherine Aley published their *Groundwater Study: Ozark National Scenic Riverways* in 1987, they had conducted at least one trace of every major spring that feeds the Current. They included a series of maps delineating the recharge areas for all major springs.[6]

Pigeon Creek and Montauk Spring form the head of the Current River. The creek and the river provide the only surface water found in Montauk State Park. Losing sections of the creek's upper reaches contribute water to the spring.[7]

Or is it Montauk Springs? In 1892, heavy rains and flooding washed gravel into the bedrock opening of the spring, clogged it, but did not plug it. The spring disbursed and emerged from several smaller pools, gravel bars, and creek beds. Walk along the creek that emerges from the spring. "You will see water springing from very small ponds, from seeps, from its gravel bed."

The sources of Montauk Spring puzzled geologists for decades. It puzzled geologists James Maxwell and David Hoffman. In the fall of 1971 the pair toured the region east of Licking for their study of *Water Resources of the Current River* and speculated on suitable places where they could inject dye the following spring. They ruled out Monty Spring, which spills into a stream that cuts through a steep-sided hollow, where beaver had built a dam across the stream. They considered a huge sinkhole, 600 feet wide northeast of Licking, which drained runoff from the surrounding pastureland and could carry water into a subterranean system.[8]

April 18, 1978, Tom Aley took up the Montauk Spring puzzle in his study of water resources west of the Current River. He injected eight pounds of dye into an unnamed tributary of Bean Creek. The creek meandered across the woodland plain near Licking at the rate ten gallons per minute. He placed charcoal packets in both Montauk and Welch springs. The dye first showed up in Montauk on May 1. It also showed up in Welch Spring two days later. Big surprise. And it showed up in an unnamed spring in Bean Creek on about May 10. Only when he viewed the packets under very intense light could he read the

Montauk Spring Brook

results: positive, but very weakly positive. Aley considered, for the first time, that the springs in the Current River watershed share recharge areas. A decade later when he recovered contradictory weak results from injection sites at the head and foot of Gladden Creek, east of the Current, he concluded that Current River springs often share common recharge areas.[9]

Montauk Spring: Cameron Road Sinkhole Trash

"No Dumping." So said a sign at the sinkhole; so said Tom Aley. Aley concluded his Hurricane Creek study by noting:

> Protection and management of the springs and rivers of the study area requires protection and management of the land tributary to these features. It is impossible to manage the spring effectively without managing the land, which supplies recharge water for the springs. In the study area, and in many other soluble rock lands as well, the surface and the subsurface are an intimately integrated system. The surface affects the subsurface and vice versa. Similarly, surface management affects the subsurface; subsurface management affects the surface.

Sinkholes and losing streams can speed contaminants directly into the underground system and foul groundwater. The earliest demonstration of the role of sinkholes and losing streams in the contamination of groundwater came in 1920 when the Mid-Continental Iron Company disposed of waste isopropyl alcohol in Davis Creek, a losing stream, filled with sinkholes. The alcohol showed up in Big Spring, which carried it to the Current River, which fouled the drinking water of the City of Doniphan, 30 miles downstream.[10]

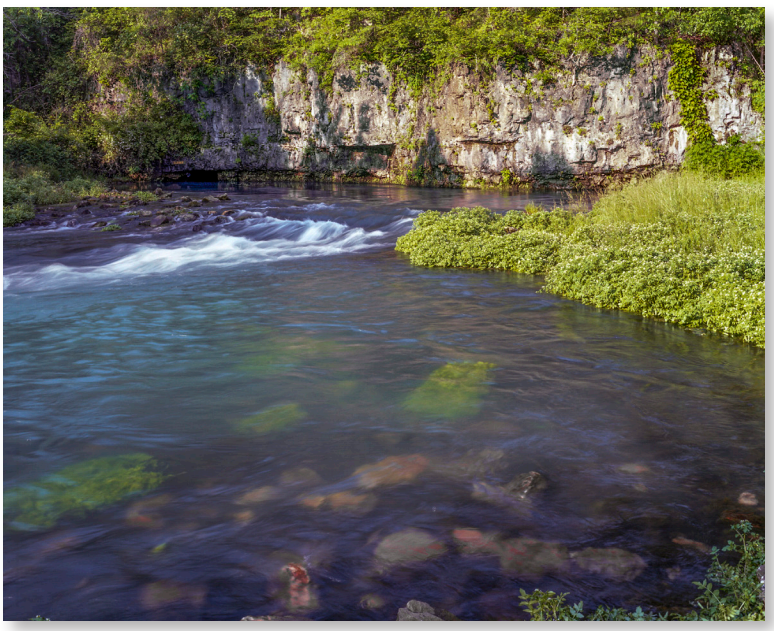
Right outside of Licking and a half-mile north of the site of Aley's Bean Creek trace, Cameron Road dodges a sinkhole in the woodland plain, a natural place to inject dye. In September 1986 Marian Gooding, a naturalist at Montauk State Park who worked with James Vandike, a geologist with the Department of Natural Resources, did just that. She recovered her charcoal packet in Montauk Spring two weeks later.[11]

Welch Spring: New Harmony, Missouri 32

Anne Keller, a master's candidate in geology at the Missouri University of Science and Technology, confirmed Gooding's trace. During a thunderstorm in May 1999, she poured nine pounds of dye into a stream of water, spilling into the sinkhole at 20 gallons a minute. She recovered her dye packet at Montauk Spring, almost eight miles from the sinkhole.

Keller's focus, however, was Welch Spring, not Montauk. The four additional traces she ran for her thesis delineated the extent of the Welch Spring recharge area, which reaches north and east of the Current and into the losing streams that form the Meramec headwaters.[12]

Paddlers on the Current River put in at Akers Ferry, just downstream of Welch Spring, the third largest spring in Missouri and the second on the Current River, for a very good reason. The spring spews from a cave at the rate of 229 cubic feet per second and turns the river from a lazy stream into a first-class float. Welch Spring's 214-square-mile recharge area reaches under the Ozark Plateau divide and into Meramec drainage area. Sinkholes, 284 of them, pockmark its recharge area. When it rains, those sinkholes drain surface water into the underground system. So do losing streams. Historically, poorly drained fragipan soils hosted post-oak barrens. Welch spring draws its water from a variety of landscapes: fragipan soils that have been converted to pasture; gravel-bedded losing streams that run though woodlands; Gladden Creek, a broad losing stream bordered by forests.[13]



Welch Spring

For visitors to the central Ozarks, the prairie ridges, where cattle graze in fescue pastures, are places to get through on the way to someplace else: Montauk Spring or Round Spring or the new Echo Bluff State Park along Sinking Creek. South of Salem, Missouri, 19 crosses Missouri 32 riding the ridge that separates the Gladden Creek watershed from the Sinking Creek watershed, eastern tributaries to the Current River that supply water to Welch and Cave Springs. Along the way, it cuts across plains in the Meramec watershed and woodlands in the Current watershed, and finally enters the Current River Forest Breaks. It crosses the Current River at Round Spring and continues its twisting way south.

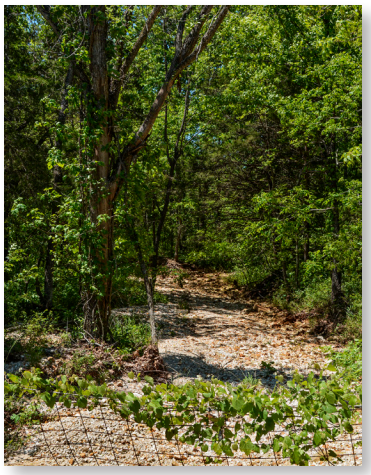
Above Missouri 32, the Meramec is a gaining stream as it draws water from its headwater tributaries. Below Missouri 32, its headwater tributaries are losing streams. The sinking creek at New Harmony on 32 was not your conventional injection site. On March 23, 1982, when Tom Aley mixed the dye for the New Harmony trace, he decided to use more than normal. The stream—a tributary of Dry Creek, a losing stream in the Meramec Basin—flowed at a mere 15 gallons per minute. Aley's dye seeped into the underground system through a

The spring spews from a cave at the rate of 229 cubic feet per second *and turns the river from a lazy stream into a first class float.*

Description of Welch Spring coming out of a cave on the Current River

boggy place, lined with fine-grained sediments rather than coarse gravel.

Nevertheless, he set his packets in Welch Spring. Not until May 4th did dye show up at the spring and with weakly positive results. For 64 days after the March injection Aley continued to receive weak results. He attributed his results to his less-than-ideal site and speculated that because it is in the northern-most reach of the Welch recharge area and the Meramec River topographical basin, the dye might have been diverted to other springs to the north and northwest. He recommended further study.[14]



Welch Spring: Wofford Branch of the Upper Meramec

In 1999, Anne Keller studied the New Harmony trace and replicated Aley's trace without success. However, her trace in the Wofford Branch of the Upper Meramec extended the limits of the Welch Spring recharge area. It rained heavily on the night of May 4. The next day, Keller dropped dye into the Wofford Branch of the Meramec, which threads a densely treed hollow in the Mark Twain National Forest. Water carried the dye a mile and a half downstream at 10 gallons per minute, where it sunk into the gravel bed of the losing stream. She recovered her packet from Welch Spring.[15]

The confluence of two losing streams, Standing Rock Creek and Gladden Branch, forms Gladden Creek, a tributary of the Current River. The large losing stream maneuvers a serpentine hollow through woodlands into the forest breaks and drains the region east of the Current.

If the New Harmony injection site was anything but ideal for a Welch Spring trace, the Gladden Creek site, just north of the Dent/Shannon County line, was. The spring was only 17,900 feet away. The water ran at the site at 20 gallons per minute and continued to do so for all 43 days of the May 1982 trace. Eight gallons of dye should have shown moderate or even strongly positive results at Welch Spring.

On May 12, 1982, the Aleys injected their dye into Gladden Creek and set their packets in Welch and Cave springs and two other places. The dye promptly sank into the sandy and gravel creek bed and showed up, with weakly positive results, at Cave Spring. Why?

Maybe 43 days of sampling was not enough. Yes, but a wave of storms after May 12 should have flushed the dye into the underground system. Maybe the dye went to places they didn't sample, such as other springs along the Current. Maybe the layers and layers of deep sand and gravel in the creek bed soaked up the dye and it never entered the underground system to Cave Spring.

In 1985, Aley injected six pounds of dye into the head of Gladden Creek just south of the confluence of Standing Rock Creek and the Gladden Branch, where water ran at 75 gallons per minute. He set his dye packets in four places: Welch and Cave springs and Gladden Creek at KK Road in Dent County. Finally, he set packets in Montauk Spring to test whether it draws water from the east side of the river. Welch Spring tested strongly positive within three weeks. Montauk Spring tested negative.

Tom Aley's 1978 trace at Bean Creek had alerted him to the possibility that a single losing stream could deliver water to two, maybe even three, different springs.[16]

At 19, Jerry Vineyard descended into Devils Well for the first time. Five years later, in

Welch Spring: Gladden Creek

The Pulltite Springs complex, Round Spring, and the Current River Springs complex *all deliver water to an 11.3-mile stretch of the Current.*

1961, Vineyard—now a geologist, working on his master's thesis at the University of Missouri—conducted the first Missouri dye trace to a Current River spring that used a charcoal packet to absorb dye. He was almost certain the well and the spring were connected. He secured a packet in Cave Spring on the Current River and dropped the dye in Devils Well—a mile away. He waited a week for the dye to show up in the spring. Thomas Aley's traces, made in the last decades of the twentieth century, demonstrated that Cave Spring shares parts of its recharge area with Welch Spring.

Cave Spring Photograph by Joyce Hoffmaster, Cave Research Foundation

Like Gladden Creek, Sinking Creek collects water from a series of losing streams and delivers it to the Current River. Two traces 26 years apart proved that its losing branches deliver water to Cave Spring.

Tom Aley delineated the recharge area of Cave Spring 21 years after Vineyard's 1961 trace and demonstrated that it draws water from east of the Current River. On March 9, 1982, Aley dropped dye in the Pankey Branch of Big Barren Fork of Sinking Creek in Dent County. He placed charcoal packets in Welch Spring, Cave Spring, others along the Current south of Cave Spring, as well as two places along the Barren Fork. He left enough packets in Cave Spring to study the results for three months. By day 35 he had strongly positive results, but negative in the month after that. However, he uncovered weakly positive results over the next five weeks, which he attributed to a second trace he made to Cave Spring.

The Pankey Branch, a losing stream, runs through Asbridge Hollow, a pretty, narrow green hollow. Horses, a possible source of groundwater contamination, graze near its head. About a mile from its head, a spring in its west bank delivers water to it. Downstream a young bottomland forest finds anchor in its alluvium.

On July 17, 1998, Anne Keller poured five pounds of dye into the spring and set her charcoal packets in Cave Spring. The stream carried the dye a mile downstream at the rate of 75-100 gallons per minute. It disappeared into coarse gravel near the Bedwell Cemetery, never to reappear. Pankey Branch ran dry beyond the losing point. Tom Aley noted when he made his 1982 trace at Pankey Branch that the creek ran dry to within a half-mile of its confluence with Big Barren Fork.[17]

The Pulltite Springs complex, Round Spring, and the Current River springs complex all deliver water to an 11.3-mile stretch of the Current. This series of springs draws from overlapping recharge areas that extend to the western limits of the Current River watershed. Some of the springs in the Current River complex rise in the river and are difficult to trace back to their sources. Aley used those that rise in its floodplain to trace the sources of the complex.

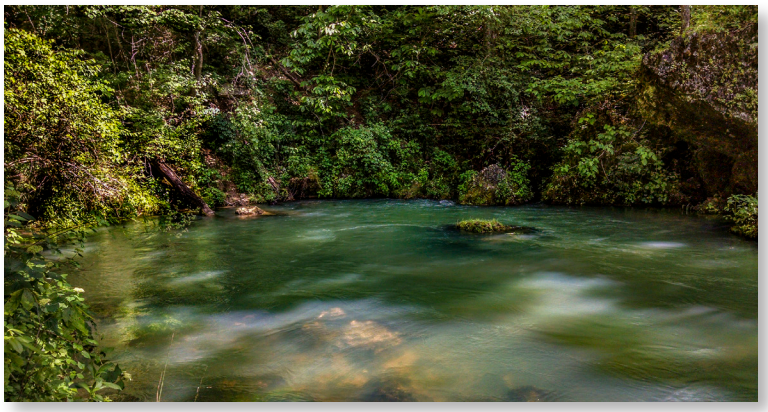
The Pulltite Spring complex—Pulltite, Fire Hydrant, Gravel, Boiling Sand, and two unidentified springs between Pulltite and Lewis Hollow—draw water from the Sunklands and the dissected region to the west. Tom Aley performed four traces on the complex from different sites, in 1976, 1978, and two in 1986.

Big Creek rises at the eastern edge of the Summerville Savanna Plain outside the Current River Hills, flows northeast across the dissected Current River Plain, and reaches its confluence with the Current four miles north of Welch Spring.

Aley chose two sites along the creek to run traces. On June 16,

Cave Spring: Pankey Branch of the Big Barren Fork, Asbridge Hollow

Pulltite Spring Complex: Lower Big Creek



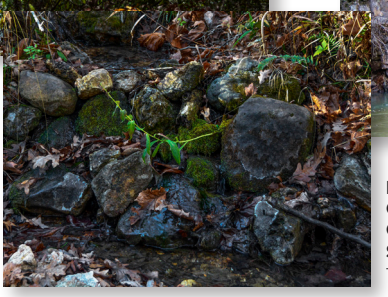
Pulltite Spring Photograph by Jennifer Swab, *(Courtesy of the Ozark National Scenic Riverways)*

1978, Tom Aley injected eight pounds of dye into the confluence of Big Creek and Dry Bone Creek in rough country west of the Sunklands. He left carbon packets in Alley Spring and the Pulltite Spring complex. The Alley Spring packet proved negative. When Aley retrieved his packets in the Pulltite complex on June 27, his results were negative. However, the packets at Lewis Hollow showed very weakly positive results. He placed additional packets in the springs in the Pulltite complex on the 27th and left them there until July 18, with very strongly positive results at all sites.

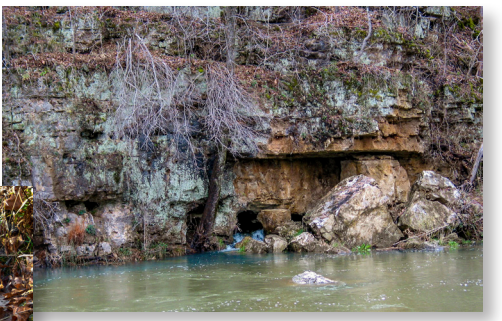
Missouri KK in Texas County drops more than 200 feet through the Current River Woodland Plain and through the Current River Forest Breaks to Lower Big Creek. Sycamores, bottomland trees, line its narrow bank. Everett Chaney, Aley's associate on the ONSR project, twice injected dye into the creek at its crossing with KK road. On April 2,1986, he set packets at multiple sampling stations: Round Spring and above its spring branch on the Current River; at Pulltite, Fire Hydrant, Gravel, and Boiling springs in the Pulltite complex; and at Cave, Welch, and Montauk springs. When he collected the packets two weeks later, all results proved negative save the weak results from the Pulltite complex, which surprised him. He had expected strongly positive results for all springs in the Pulltite complex. He repeated the trace on April 27 and added six additional sites to his test. He recovered positive results, strongly positive, only from springs in the Pulltite complex. Given their results from traces at two sites along Big Creek, Aley and Chaney concluded that the creek delivers water only to the Pulltite complex.

When Chaney added up the mean annual flow of each of the springs in the Pulltite complex plus the unidentified springs between Pulltite and Little Fields Hollow, he came up with a recharge area of 223 square miles, using the formula of one square

Pulltite Complex to Current River Complex: Sunklands Conservation Area, Sinkhole Pond



Mill Hollow Creek-Current River Spring Complex



Fire Hydrant Spring emerges from a cave about three feet above the Current River. *(Photograph by Scott House, Cave Research Foundation)*

mile of recharge area for every cubic foot of discharge. It's a region that covers both the Big Creek watershed and the Sunklands Conservation Area.[18]

Sunklands Conservation Area straddles the irregular boundary between the Summersville Oak Savanna/Woodland Plain and the Current River Oak-Pine Woodland Forest Hills. In December 1991 the Nature Conservancy and the Missouri Department of Conservation signed a deed for the purchase of 80,819 acres from the Kerr-McGee Corporation in Shannon, Carter, and Wayne counties. Kerr-McGee had managed the land conservatively, selectively cutting instead of clear-cutting its timber. Therefore, the Nature Conservancy was comfortable negotiating a deal for $10.1 million. It planned to sell some of the land to the Missouri Department of Conservation and retain some for its own nature preserves.[19]

Almost half the MDC land went into the Sunklands Conservation Area, 37,440 acres of the Kerr-McGee acquisition. The MDC reserved 5,700 areas within the area as a natural area, off limits to logging, motor homes, wooden structures, and human occupation, though it is possible to drive through it. At the core of the natural area is the Sunkland, the collapse of a massive cavern, a depression in the landscape, almost a mile long and 600 feet wide, containing a sinkhole or a series of sinkholes, some dry, some filled with water. A mile away in the Burr Oak Basin, Tom Aley performed two dye traces in one of three sinkholes, clustered together. The first, in March 1976, yielded inconclusive results. The second, ten years later, yielded stunning results.[20]

Everett Chaney performed the second trace on December 5, 1986. He dropped his dye in water, which was overflowing a small pond at the rate of five gallons per minute. It carried Chaney's dye into a sinkhole, one of three in the cluster in Burr Oak Basin. He set his packets in 14 places, including the springs in the Pulltite Complex and Round Spring. The dye showed up first in Fire Hydrant Spring. Soon after he recovered positive results from Pulltite, Gravel, and Boiling Sand springs in the Pulltite complex. The packet he set in Round Spring showed weakly positive results. Finally, dye showed up in packets in springs in the Current River Complex, downstream of Round Spring, giving him positive results on an 11.3-mile stretch of river between Pulltite and Barn Hollow Spring. The trace demonstrated that the Pulltite complex shares a portion of its recharge area with Round Spring and the Current River complex, whose existence was unknown until April 1978, when Aley injected dye into a losing section of Mill Hollow Creek.[21]

Tom Aley made two traces in 1976, one from Cox Cave and the other from the Sunklands. He set his packets in springs in the Pulltite complex and saw no results. The dye had disappeared into a "black hole." Two years later, he trekked down into Mill Hollow, deep in the Current River Forest Breaks, where water trickles over rocks to the Current River at the rate of 0.1 cubic feet per second. At noon on April 5, 1978, Tom Aley injected dye into a losing section of the stream. It showed up the next morning in springs at the mouth of Mill Hollow with very strongly positive results. It also showed up at the mouth of Root Hollow with very weakly positive results two weeks later. The trace did not show up in Round Spring.

Because he suspected that the dye at Root Hollow came from surface water, he left packets in place. They absorbed more dye.

"Suddenly, there was a **roar** of water..."

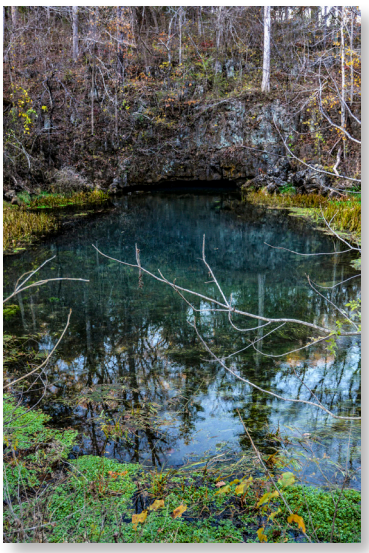
Aley attributed these results to groundwater discharge from springs in the hollow. He had found an explanation for the "black holes" in the channel of the Current River and the Current River complex.[22]

For the untutored, Round Spring should stream out from under the natural arch of Eminence Dolomite, the remnant of a collapsed cave. Not so. When the roof of the Round Spring cavern collapsed, it revealed a spring, rising in a circular basin. Boulders from the fallen roof blocked the underground channel that supplies the spring, preventing divers from exploring the conduit beyond a depth of 55 feet.

Round Spring rises in its circular basin and streams under the arch to its spring brook, which carries it to Spring Valley Creek and the Current River. The spring draws water from a 119-square-mile recharge area and flows at the rate of 46.9 cubic feet per second.

When Missouri set up its system of state parks in the 1920s, Governor Arthur M. Hyde and his fish and game commissioner, Frank Wielandy, looked to the Ozarks, where land was cheap, the natural landscape intriguing, and therefore, the interest great. While Big Spring, the first park, came into the system in 1924, a year before Hyde left office, Round Spring did not until 1932. In 1967, the State of Missouri gave Round Spring, Alley Spring, and Big Spring, all state parks along the Current and Jacks Fork, to the National Park Service for inclusion in the Ozark National Scenic Riverways.[23]

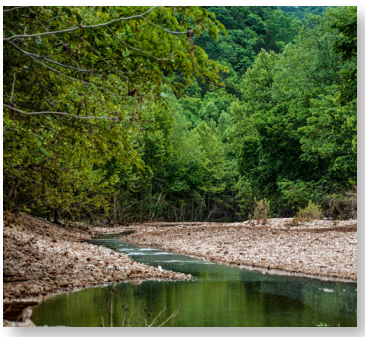
Round Spring



"Suddenly, there was a roar of water and the previously dry bed of Spring Valley, by which we had camped, was filled with a rushing torrent 4 to 10 feet deep and 30 to 100 feet wide." Edward Seymour Woodruff encountered Spring Valley Creek when he camped by it in 1908. It's a classic losing stream that rises on the savanna/woodland plain west of Summersville and loops across the hills in the Sunklands Conservation Area. It makes one final large horseshoe turn at George Hollow before streaming past tall bluffs near its mouth.

Monsoon-like rains at the end of April 2017 flooded the Current River landscape, including its many losing streams. By mid-May, water still flowed in losing streams like Spring Valley Creek. Normally, it would not take three weeks to drain floodwater at George Hollow. Normally, in May, young crops would be sprouting on the agricultural fields that line the creek. But the April 2017 showers were no gentle spring rain, and the hollow remained flooded well into May.

On June 1, 1978, Tom Aley injected six pounds of dye into the mouth of George Hollow, which was running at 40 gallons per minute from a spring in the hollow. He set his packets in Round Spring, at the mouth of Spring Valley Creek at the Round Spring campground and at the mouth of Root Hollow. The results everywhere were very weakly positive. He set a second set of packets in Round Spring on June 15 and left them through June 26, with strongly positive results.[24]



Round Spring: Spring Valley Creek, George Hollow

Spring Valley Creek rises in the Summerville Plain and meanders across the Current River watershed to its confluence with the Current, a straight-line distance of about 18 miles. It loses water to both Alley Spring on the Jacks Fork near its head and Round Spring on the Current River near its mouth. In April 1978, Tom Aley located an injected site on Spring Valley Creek west of Summersville. He injected eight pounds of dye into a spring branch 50 feet north of its confluence with the creek. The dye disappeared into the losing stream. He placed charcoal packets in both Blue Spring on the Jacks Fork and Alley Spring. His trace arrived about two weeks later at Blue Spring, 47,500 feet away, and showed weakly positive results. His results at Alley Spring

Spring Valley Creek West of Summersville-Blue Spring (Jacks Fork) and Alley Spring

were very weakly positive during the same two-week period. However, the trace yielded strongly positive results two weeks later. The dye streamed at a rate of 211 feet per hour over a straight-line distance, or 76,000 feet between the creek and the Alley Spring.[25]

Blue Spring shares its catchment or recharge area with Alley Spring, and, while much of the Alley Spring recharge area is forested, much of the area it shares with Blue Spring has been cleared for pasture. The Jefferson City-Cotter formation, pockmarked with sinkholes, dominates its catchment area. Hydrologists suspect that rain, washing off pastures into sinkholes and underground channels, can carry non-point pollution to Blue Spring and the upper Jacks Fork. Algal blooms follow.

Jack Toll, speaking to oral historians with the U.S. Geological Survey in 1993, noted, "We never had algae blooms. I mean big ones. They occur all up and down the river on both prongs. They get so bad in the summer that when they die and float to the top, you just can't fish. Huge algae blooms. And they were not there two years ago. Seems like it starts in late July and then they bloom and there's just this green stuff that's everywhere."[26]

A National Park Service study of water quality on Jacks Fork and Current rivers showed that springs in general had the highest concentrations of nitrates, and Alley Spring topped the list. The study concluded that springs are more likely to show the effects of land use in their watersheds than do the rivers they feed. Hence, if Alley Spring shares part of its catchment with Blue Spring and much of that area is devoted to pasture that has been fertilized with nitrates, then Alley Spring will have higher levels of nitrates than other springs.[27]

By 2016 the pasture that surrounds the Horton Davis sinkhole on the Summerville plain had turned to scrub. Trees grow on its sides. Not so on November 1, 1972.

It rained hard the day Thomas Aley and Everett Chaney dropped ten pounds of fluorescein dye in the Horton Davis sinkhole, which is 30 to 40 feet deep. Theirs was the first attempt to define the Alley Spring recharge area. Water drained off the surrounding pasture into the sinkhole at the rate of two cubic feet per second and ponded there to a depth of 15 feet. While Aley and Chaney recovered their charcoal packets from Alley Spring November 9, they figured the dye had arrived around November 5. The packets showed a moderately positive result. The dye had traveled 58,100 feet at the rate of 605 feet an hour and confirmed that the Summerville Plain forms the recharge area for Alley Spring.[28]

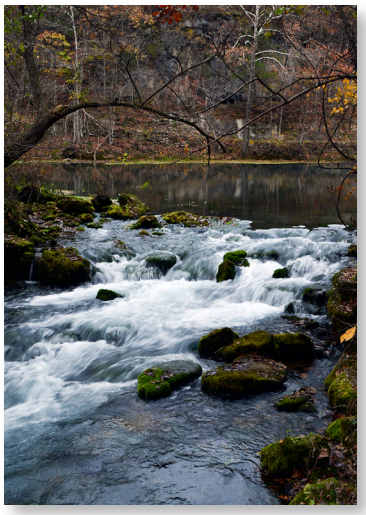
Blue Spring Access, Jacks Fork

In his 1930 study of the Eminence and Cardevara quadrangles, Josiah Bridge tells the story of the day Alley Spring stopped flowing for twelve hours. It seems a large sinkhole had formed and plugged the underground conduit with muddy debris. When flow resumed, mud flowed into the spring. It took days for it to clear.[29]

Thomas Aley tells a similar story with a different conclusion. In April 1974, flow from Alley Spring jumped to 2,750 cubic feet per second (cfs) after a heavy rain, 1,700 cfs more than the previous peak recharge of 1,060 cfs in March 1935. Aley noted that losing streams have a finite recharge capacity. Once exceeded, their surplus water flows on the surface. Hence, if losing streams were incapable of delivering such a huge quantity of water to Alley Spring, it must be the sinkholes that surround Summersville. He concluded that gullies lace the sinkhole plain and carry water to the sinkholes, like the Horton Davis, which form a "large capacity spring system capable of rapidly transporting subsurface waters."[30]

South of the confluence of the Current and Jacks Forks rivers, the Eminence Caldera, fifty isolated knobs of rhyolite, lies at the center of the Ozarks National Scenic Riverways. Much like the Early Cambrian seas, which deposited the Lamotte and Bonneterre Formations between the knobs of the St. Francois Mountains, the Late Cambrian seas seeped between the igneous knobs of the Eminence Caldera and deposited the Potosi and Eminence formations on the valley floors and the Gasconade and Roubidoux formations above. The Current flows past or threads between the knobs: Jerktail, Coot, Wildcat, Williams Mountains, and various unnamed knobs. It bends to the south at Owls Bend and flows south, touching the eastern edge of a series of knobs: Mill Mountain, Thorny Mountain, Stegall Mountain, and more unnamed knobs.

The geological maps of the Eminence Caldera, particularly the Stegall Mountain map, show that pockets of Cambrian sedimentary rocks are scattered between the knobs. The Late Cambrian seas flooded in, deposited the Potosi, Eminence, Gasconade, and Roubidoux formations, and buried the knobs. The streams, be it the Current River, the Jacks Fork, or even Rocky Creek, meandered across them. When the knobs uplifted, the streams maintained their courses and simply eroded canyons into the saddles between the knobs and removed the sedimentary rocks clear down to rhyolite, forming shut-ins. Or possibly, the streams eroded headward, encountered a knob, found a weak place in the volcanic rock, and carved a narrow canyon, a shut-in, through it. While Rocky Falls looks more like a waterfall than a classic shut-in like Johnson's Shut-in in Reynolds County, the creek wore down the Eminence and Gasconade formations between Buzzard and Mill mountains to form a unique shut-in.[31]



Alley Spring

Alley Spring: Horton Davis Sinkhole

The Osage called it the "Spring of the Summer Sky,"
for its deep blue color...

Rocky Falls Shut-in

Plum Spring in the Peck Ranch Conservation Area draws its water from Upper Sycamore Creek north of Winona. The spring overflows into Mill Creek, where water falls into the underground system again and shows up in Mill Spring outside the refuge. Upper Sycamore also delivers water to Mill Spring, and Upper Sycamore, Plum Spring, and Mill Creek Spring all deliver water to Big Spring. Two traces established this complex scenario.

On August 1, 1984, Tom Aley and Everett Chaney cleared away a beaver dam that plugged a culvert on Mill Creek in the Peck Ranch refuge and increased its flow from 5 to 55 gallons per minute. Next, they poured in six pounds of dye and set their packets in Pike, House, and Mill creeks a well as Mill and Big Springs. About a half-mile upstream of their injection site, Plum Spring supplied the surface water for the creek at the rate of 1.5 cubic feet per second. Aley and Channey had no results by August 6, but by the 22nd they had strongly positive results at Mill Spring, 4.5 miles away and at Big Spring 12.4 miles away, straight-line travel. They concluded that Big Spring and Mill Creek Spring share a recharge area.[32]

The following March 19, Chaney injected dye into a losing section of Upper Sycamore Creek north of Winona. He placed packets in Mill Creek, Big, Plum Springs, and Mill Creek upstream of Mill Creek Spring. For the first week, his results proved negative. He continued testing. When he recovered packets from Mill Spring, 12.4 miles away, and Big Spring, 19.4 miles away, three week later, his results were moderately positive. His results from Plum Spring, 7.7 miles from Upper Sycamore Creek, were very weakly positive.

When Aley and Chaney examined the flow records of Mill Creek Spring, they learned that on November 20, 1942, flow at the spring dropped to zero when Big Spring was flowing at 594 cubic feet per second. When they received the results of the 1985 trace, they concluded that Big Spring is pirating water from its shared recharge area with Mill Creek Spring. That a small amount of dye showed up in Plum Creek in 1985 only adds to the complexity of the underground drainage system of the Big Spring recharge area.

The Osage called it the "Spring of the Summer Sky," for its deep blue color, a product of its depth and the load of dissolved limestone and dolomite carried through its underground channels. The spring, emerging from under a bluff of Eminence Dolomite, looks so still, but its spring brook rushes 90 million gallons of water a day a quarter mile to the Current River.

Blue Spring draws its water from Logan Creek, a losing tributary of the Black River. Once water disappears into the sinks of the creek, it must pass under the divide between the Black River and Current River watersheds. It discharges through Blue Spring at an annual flow of 140 cubic feet per second. Using the rule of thumb of one mile to one cubic foot of discharge gives the spring a 140-square-mile recharge area. Divers have probed its depth to 256 feet.

Tom Aley started work on the Hurricane Creek watershed, expecting its losing sections to deliver water to Greer Spring, a tributary of the Eleven Point River. It didn't. He started looking for the "missing water." When he conducted his Blowing Spring trace in the bed of Hurricane Creek in 1968, the "missing water" spilled into the subterranean system, crossed under the drainage divide between the Eleven Point and the Current rivers, and emerged from Big Spring. Of the 34 traces Aley ran during the Ozark National Scenic River project, 13 wound up in Big Spring, two in Greer Spring.

Missouri's interest in Big Spring started with Thomas Jacob Rodhouse's 1912 study of the flow of the Current River above and below the spring, which proved it a tributary of the river. In 1923, the state ordered a survey of water resources that might be used to

generate power. Four years later hydraulic engineer Henry Claus Beckman issued a report that concluded that Welch, Blue, and Big springs deliver enough water to the Current to maintain a uniform flow. He determined that given good dam sites, south of its confluence with the Jacks Fork, the Current could be harnessed for waterpower.[33]

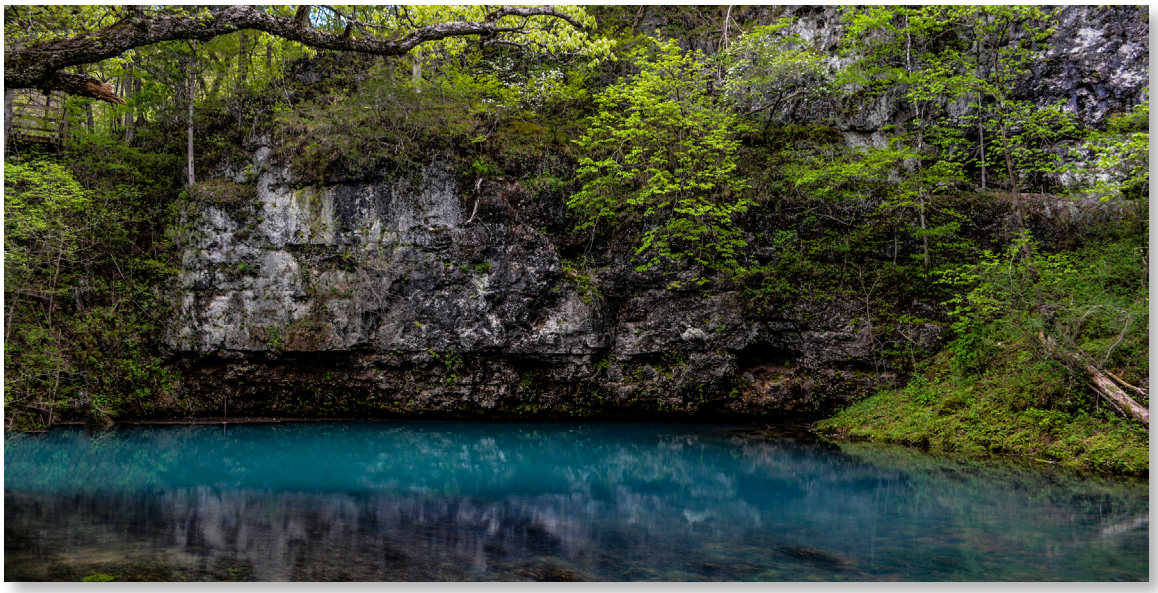
In 1924 Missouri made Big Spring its first state park. Twenty years later, Beckman and geologist Norman Shreve Hinchey published *Large Springs of Missouri*, a guide to state parks centered around springs, directed to tourists, scientists, educators, and residents who draw their water from springs. They provided readers with an understanding of the underground drainage systems that feed water to the springs.[34]

The 1962 McIntire-Stennis Act funded the Watershed Barometer Study within the U.S. Forest Service. Thomas Aley's Hurricane Creek Barometer study provided a template for the study and management of karst landscapes. Aley began his work on the karst landscape of the Current River four years later. After he completed the study in 1975, Aley went on to trace the recharge areas of the major springs along the Current River, a study he and Catherine Aley completed in 1987 for the National Park Service.

When, in 1983, USX, formerly U.S. Steel Corp, and Amax Exploration applied to the U.S. Forest Service for permission to explore for lead deposits in the Big Spring recharge area, the Aleys noted in their 1987 study that the hydrology of the Hurricane Creek watershed was too complex to allow lead mining to go forward. In the following years the USX proposal set off an explosion of research into the landscape of the Ozark National Scenic Riverways.

Between 1995 and 2001 geologists mapped the karst landscape of the Current River Hills. The project provided a geologic inventory of Ozark National Scenic Riverways, a geology-based park. In 1998, geologists mapped out land use in Current River Hills: what is forested, what is open, what is cultivated, and what is urban. Collaborators with the MDC, the University of Missouri Department of Forestry, the U.S. Geological Survey, the National Park Service, and Nature

Mill and Big Springs: Plum Spring-Peck Ranch Conservation Area



Blue Spring

Big Spring Boil

Serve mapped the vegetative communities in the Current River Hills, which provided the model for mapping the rest of the state. The work culminated in the 2002 publication of the *Atlas of Missouri Ecosystems*. In 2009 geologists turned to Thomas and Catherine Aley's 1987 *Groundwater Study of the Ozark National Scenic Riverways* to investigate the geohydrologic and landscape characteristics of the recharge areas of major springs that feed the Current and Jacks Fork.

This article would not have been possible without the help of Thomas Aley with the Ozark Underground Laboratory, who answered any questions I asked; Dena Mattesen with the Ozark National Scenic River, who arranged for Jennifer Swab's photographs of Pulltite Spring; Mike Gossett of the Ozark National Scenic River, who provided me with copies of Aley's *Groundwater Study of the Ozark National Scenic Riverways*; and photographers Scott House and Joyce Hoffmaster of the Cave Research Foundation.

Finally, geologists are a generous lot. Jerry Vineyard was no exception. After I started researching and writing this series, Jerry answered my questions and allowed me to use the graphic of Devils Well from his 1982 book *Springs of Missouri*, written with Gerald L. Feder. This article is dedicated to his memory.

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