FINAL TECHNICAL REPORT
NASA GRANT NAGW-2147
1 JANUARY 1990 - 30 SEPTEMBER 1997

Date Submitted: December, 1997

By: J. William Schopf
Principal Investigator

Table of Contents

MAJOR RESEARCH ACCOMPLISHMENTS SUPPORTED BY NAGW-2147, 1 JANUARY 1990 - 30 SEPTEMBER 1997

RESEARCH RESULTS COMMUNICATED IN EDITED BOOKS

As listed in the final section of this report, research supported by NAGW-2147, 1 January 1990 - 30 September 1997, resulted in publicaton of five edited books. Foremost among these is the award-winning volume *The Proterozoic Biosphere, A Multidisciplinary Study* (Cambridge Univ. Press).

- A monumental (1,348 pp.) research monograph, *The Proterozoic Biosphere, A Multidisciplinary Study* was completed, edited, and published (1992; Cambridge University Press). This volume provides a detailed analysis of the interrelated geologic, environmental, and biologic history of the Earth from 2,500 to 550 million years (Ma) ago on the basis of studies of 1,781 geologic samples carried out at UCLA by a team of 41 scientists from eight countries (Australia, Canada, Denmark, Germany, Russia, South Africa, Sweden, USA). ***(Reference #1.)***
- Like its predecessor published in 1983 -- a monograph by the same research team spanning the time from the origin of the Earth, 4,500 to 2,500 Ma ago, (*Earth's Earliest Biosphere, Its Origin and Evoution*; 543 pp.; Princeton University Press) -- *The Proterozoic Biosphere* was selected by the Association of American Publishers as winner of the Professional and Scholarly Publishing Award as the Outstanding Volume in Earth Science. Both award-winning monographs report research supported by NASA funding. ***(References #1, #2.)***

RESEARCH RESULTS COMMUNICATED IN JOURNAL ARTICLES AND BOOK CHAPTERS

As listed in the following section of this report, research supported by NAGW-2147, 1 January7 1990 - 30 September 1997, led to publicaton of 39 journal articles and book chapters. Principal research results thus communicated:

- Report discovery and formally describe the oldest fossils now known, 11 species of 3,465 $\pm$5 Ma-old microorganisms from the Apex chert of northwestern Western Australia ***(References #3, #4)***.
- Provide the first quantitative detailed analysis of the evolutionary development of the global ecosystem from 2,500 to 550 Ma ago ***(References #5, #6)***.
- Summarize the historical development of the emergent field of Precambrian paleobiology ***(Reference #7)***.

- Present the first detailed morphometric analysis of all known Proterozoic microorganisms providing a basis for interpretation of their affinities, geologic distribution, and evolutionary trends ***(Reference #8)***.
- Provide an up to date in-depth analysis of the time and nature of major events in Proterozoic biotic evolution ***(Reference #9)***.
- Present the single exhaustive authoritative analysis of the morphologies, biological affinities, and taxonomy of all Proterozoic microfossils now known ***(References #10, #11, #12)***.
- Present major generalizations regarding the markedly differing tempos and modes of Precambrian and Phanerozoic evolutionary histories ***(Reference #13)***.
- Elucidate the biochemical and evolutionary relations among, and the rapid Archean development of, the principal metabolic processes of the global ecosystem ***(Reference #14)***.
- Report discovery of diverse ~2,600 Ma-old stromatolitic microorganisms from South Africa that provide an important evolutionary link between the recently described Early Archean Apex microorganisms and the more or less continuous fossil record of the later Proterozoic ***(Reference #15)***.
- Provide new data regarding the cyanobacterial affinity of the oldest fossils now known, 3,465 Ma-old microbes from northwestern Western Australia ***(Reference #16)***.
- Present results of exhaustive morphometric analyses comparing ~1,500 species of living cyanobacterial and bacterial prokaryotes with a worldwide sample (~4,000 taxonomic occurrences) of Precambrian microfossils in order to elucidate patterns of microbial evolution 3,500 to 550 Ma ago ***(Reference #17)***.
- Report and describe seven newly discovered richly fossiliferous microbiotas, from Neoproterozoic (~600 to ~1,000 Ma-old) stromatolitic units of east-central Brazil including the most diverse, best preserved such microbial assemblage now known from all of South America ***(Reference #18)***.
- Use the known fossil record of cyanobacteria and the carbon and sulfur isotopic compositions of ancient sediments to evaluate the 1996 "protein clock"-based claim of Doolittle et al. that cyanobacteria date from ~1,500 Ma ago, the last common ancestor of currently living systems from ~2,000 Ma ago ***(References #19, #20)***.
- Evaluate critically recent reports of microfossil-like objects and other purported evidence of past life in Martian meteorite ALH84001 ***(References #21, #22, #23)***.

REFERENCES CITED

#1. Schopf, J. W. and Klein, C. (Eds.). 1992. *The Proterozoic Biosphere, A Multidisciplinary Study* (Cambridge University Press: New York), 1,348 pp.

#2. Schopf, J. W. (Ed.). 1983. *Earth's Earliest Biosphere, Its Origin and Evoution* (Princeton University Press: Princeton, NJ), 543 pp.

#3. Schopf, J. W. 1992. Paleobiology of the Archean. Section 1.5. In: J. W. Schopf and C. Klein (Eds.), *The Proterozoic Biosphere, A Multidisciplinary Study* (Cambridge Univ. Press: New York), pp. 26-39.

#4. Schopf, J. W. 1993. Microfossils of the Early Archean Apex chert: New evidence of the antiquity of life. *Science* **260**: 640-646.

#5. Schopf, J. W. 1991. Collapse of the Late Proterozoic ecosystem. *South African Journal of Geology* **94**: 33-43.

#6. Schopf, J. W. 1992. Patterns of Proterozoic microfossil diversity: an initial, tentative, analysis. Section 11.3. In: J. W. Schopf and C. Klein (Eds.), *The Proterozoic Biosphere, A Multidisciplinary Study* (Cambridge Univ. Press: New York), pp. 529-552.

#7. Schopf, J. W. 1992. Historical development of Proterozoic micropaleontology. Section 5.2. In: J. W. Schopf and C. Klein, (Eds.), *The Proterozoic Biosphere, A Multidisciplinary Study* (Cambridge Univ. Press: New York), pp. 179-183.

#8. Schopf, J. W. 1992. Proterozoic prokaryotes: affinities, geologic distribution, and evolutionary trends. Section 5.4. In: J. W. Schopf and C. Klein (Eds.), *The Proterozoic Biosphere, A Multidisciplinary Study* (Cambridge Univ. Press: New York), pp. 195-218.

#9. Schopf, J. W. 1992. Evolution of the Proterozoic Biosphere: benchmarks, tempo, and mode. Chapter 13. In: J. W. Schopf and C. Klein (Eds.), *The Proterozoic Biosphere, A Multidisciplinary Study* (Cambridge Univ. Press: New York), pp. 583-600.

#10. Mendelson, C. V. and Schopf, J. W. 1992. Proterozoic and selected Early Cambrian microfossils and microfossil-like objects. Chapter 22. In: J. W. Schopf and C. Klein (Eds.), *The Proterozoic Biosphere, A Multidisciplinary Study* (Cambridge Univ. Press: New York), pp. 865-951.

#11. Schopf, J. W. 1992. Atlas of representative Proterozoic microfossils. Chapter 24. In: J. W. Schopf and C. Klein (Eds.), *The Proterozoic Biosphere, A Multidisciplinary Study* (Cambridge Univ. Press: New York), pp. 1055-1117.

#12. Schopf, J. W. 1992. Informal revised classification of Proterozoic microfossils. Chapter 25. In: J. W. Schopf and C. Klein (Eds.), *The Proterozoic Biosphere, A Multidisciplinary Study* (Cambridge Univ. Press: New York), pp. 1119-1168.

#13. Schopf, J. W. 1994. Disparate rates, differing fates: The rules of evolution changed from the Precambrian to the Phanerozoic. *Proceedings of the National Academy of Sciences USA* **91**: 6735-6742.

#14. Schopf, J. W. 1995. Metabolic memories of Earth's earliest biosphere. In: C. Marshall and J.W. Schopf (Eds), *Evolution and the Molecular Revolution* (Jones and Bartlett: Boston, MA), 73-107.

#15. Altermann, W. and Schopf, J. W. 1995. Microfossils from the Neoarchean Campbell Group, Griqualand West Sequence of the Transvaal Supergroup, and their paleoenvironmental and evolutionary implications. *Precambrian Research* **75**: 65-90.

#16. Schopf, J. W. 1996. Cyanobacteria: Pioneers of the early Earth. - *Desikachary Festschrift Volume, Nova Hedwigia* **112**: 13-32

#17. Schopf, J. W. 1996.. Are the oldest fossils cyanobacteria? In: Roberts, D. McL., Sharp, P., Alderson, G. and Collins, M. (Eds.), *Evolution of Microbial Life,* Society for General Microbiology Symposium 54 (Cambridge Univ. Press: Cambridge, UK), pp. 23 - 61.

#18. Fairchild, T. R., Schopf, J. W., Shen-Miller, J., Guimaraes, E. M., Edwards, M. D., Lagstein, A., Li, X., Pabdst M. and de Melo-Filo, L. S. 1996. Recent discoveries of Proterozoic microfossils in south-central Brazil. *Precambrian Research* **80**: 125-152.

#19. Schopf, J. W. In Press. Tracing the roots of the Universal Tree of Life. In: A. Brack (Ed.). *The Molecular Origins of Life: Assembling Pieces of the Puzzle* (Cambridge Univ. Press: New York).

#20. Schopf, J. W. In Press. The Fossil Record: Tracing the roots of the Cyanobacterial Lineage. In: B. Whitton and M. Potts (Eds.), *Ecology of Cyanobacteria: Their Diversity in Time and Space* (Kluwer Academic: Dordrecht, The Netherlands).

#21. Schopf, J. W. 1996. Confessions of a Mars skeptic. *Los Angeles Times,* August 18, 1996, p. M5.

#22. Schopf, J. W. 1996. Scientist calls for rock-hard proof of Mars Life. *UCLA Today* **17**(2) [August 30, 1996), p. 4.

#23. Schopf, J. W. In Press. Breakthrough discoveries: Extraordinary claims! Extraordinary evidence? In: J.W. Schopf (Ed.), *Evolution! Facts and Fallacies* (Academic Press: San Diego, CA).

PUBLISHED CONTRIBUTIONS SUPPORTED BY NAGW-2147, 1 JANUARY 1990 - 30 SEPTEMBER 1997

As listed below, results of research supported wholly or in part by NAGW-2147 have been communicated in a total of 84 contributions (5 edited books; 39 journal articles and book chapters; 15 book-related items; 3 miscellaneous publications; 15 abstracts; and one edited book and six other contributions currently In Press).

EDITED BOOKS

1. SCHOPF, J. W. (Ed.). 1992. Major Events in the History of Life (Jones and Bartlett: Boston), 190 pp.
2. SCHOPF, J. W. and KLEIN, C. (Eds.). 1992. The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge University Press: NY), 1348 pp.
3. CAMPBELL, J. H. and SCHOPF, J. W. (Eds.). 1994. Creative Evolution?! (Jones and Bartlett: Boston), 112 pp.
4. MARSHALL, C. and SCHOPF, J. W. (Eds.). 1995. Evolution and the Molecular Revolution (Jones and Bartlett: Boston), 166 pp.
5. SCHEIBEL, A. B. and SCHOPF, J. W. (Eds.). 1997. The Origin and Evolution of Intelligence (Jones and Bartlett: Boston), 169 pp.

JOURNAL ARTICLES AND BOOK CHAPTERS

1. SCHOPF, J. W. 1991. Collapse of the Late Proterozoic ecosystem. S. Afr. J. Geol. **94**: 33-43.
2. SCHOPF, J. W. 1992. The oldest fossils and what they mean. In: J. W. Schopf (Ed.), Major Events in the History of Life (Jones and Bartlett: Boston, MA), pp. 29-63.
3. SCHOPF, J. W. 1992. Introduction. Geology and Paleobiology of the Archean Earth. Section 1.1. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 5-6.
4. SCHOPF, J. W. 1992. Paleobiology of the Archean. Section 1.5. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 26-39.
5. SCHOPF, J. W. 1992. Geology and paleobiology of the Archean Earth: current status and future research directions. Section 1.6. In: J. W. Schopf and C. Klen (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 41-42.
6. SCHOPF, J. W. 1992. Historical development of Proterozoic micropaleontology. Section 5.2. In: J. W. Schopf and C. Klein, (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 179-183.
7. SCHOPF, J. W. 1992. Proterozoic prokaryotes: affinities, geologic distribution, and evolutionary trends. Section 5.4. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 195-218.
8. MENDELSON, C. V. & SCHOPF, J. W. 1992. Proterozoic and Early Cambrian acritarchs. Section 5.5. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 219-232.

9. MOORE, T. B., HORODYSKI, R. J., LIPPS, J. H., & SCHOPF, J. W. 1992. Distinctive problematical Proterozoic microfossils. Section 5.6. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 233-235.
10. MENDELSON, C. V. & SCHOPF, J. W. 1992. Proterozoic and selected Early Cambrian microfossils: prokaryotes and protists. Unsolved problems and future research directions. Section 5.8. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 241-242.
11. MENDELSON, C. V. & SCHOPF, J. W. 1992. Proterozoic and selected Early Cambrian microfossils: prokaryotes and protists. Summary and conclusions: the current status of Proterozoic micropaleontology. Section 5.9. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 243-244.
12. WALTER, M. R., GROTZINGER, J. P. & SCHOPF, J. W. 1992. Proterozoic stromatolites. Section 6.2. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 253-260.
13. WALTER, M. R., BAULD, J., DES MARAIS, D. J. & SCHOPF, J. W. 1992. general comparison of microbial mats and microbial stromatolites: bridging the gap between the modern and the fossil. Section 6.11. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 335-338.
14. SCHOPF, J. W. 1992. Stratigraphic distribution of prokaryotes and acritarchs. Section 10.3. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 497-498.
15. SEPKOSKI, J. J., Jr. & SCHOPF, J. W. 1992. The Proterozoic fossil record: special problems in analyzing diversity patterns. Section 11.2. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 525-527.
16. SCHOPF, J. W. 1992. Patterns of Proterozoic microfossil diversity: an initial, tentative, analysis. Section 11.3. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 529-552.
17. SEPKOSKI, J. J., Jr. & SCHOPF, J. W. 1992. Proterozoic and earliest Phanerozoic biotic diversity: unsolved problems and future research directions. Section 11.5. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 563-564.
18. SEPKOSKI, J. J., Jr. & SCHOPF, J. W. 1992. Biotic diversity during Proterozoic and earliest Phanerozoic time: summary and conclusions. Section 11.6. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), p. 565.
19. SCHOPF, J. W. 1992. Evolution of the Proterozoic Biosphere: benchmarks, tempo, and mode. Chapter 13. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 583-600.
20. MOORE, T. B. & SCHOPF, J. W. 1992. Geographic and geologic data for PPRG rock samples. Chapter 14. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 603-693.

21. STRAUSS, H., DES MARAIS, J. D., HAYES, J. M., MOORE, T. B. & SCHOPF, J. W. 1992. Flow chart and processing procedures for rock samples. Chapter 15. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 695-698.
22. MENDELSON, C. V. & SCHOPF, J. W. 1992. Proterozoic and selected Early Cambrian microfossils and microfossil-like objects. Chapter 22. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 865-951.
23. SCHOPF, J. W. 1992. Atlas of representative Proterozoic microfossils. Chapter 24. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 1055-1117.
24. SCHOPF, J. W. 1992. Informal revised classification of Proterozoic microfossils. Chapter 25. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 1119-1168.
25. SCHOPF, J. W. 1992. The oldest evidence of life. In: J.and K. Tran Thanh Van, J. C. Mounolou, J. Schneider, and C. McKay (Eds.), Frontiers of Life (Editions Frontieres: Gif-sur-Yveete Cedex, France), 235-259.
26. SCHOPF, J. W. 1993. Microfossils of the Early Archean Apex chert: new evidence of the antiquity of life. Science **260**: 640-646.
27. SCHOPF, J. W. 1994. Disparate rates, differing fates: The rules of evolution changed from the Precambrian to the Phanerozoic. Proc. Nat. Acad. Sci. USA, **91**: 6735-6742.
28. SCHOPF, J. W. 1994. The early evolution of life: Solution to Darwin's dilemma. Trends in Ecology & Evolution, **9**: 375-377.
29. SCHOPF, J. W. 1994. The oldest known records of life: stromatolites, microfossils, and organic matter from the Early Archean of South Africa and Western Australia. In: S. Bengtson (Ed.), Early Life on Earth (Columbia University Press: New York), 193-206.
30. SCHOPF, J. W. 1995. Ritmo e modo da evolução microbiana pré-cambriana. Estudos Avançados **9**(23): 195-216 (in Portuguese).
31. SCHOPF, J. W. 1995. Disparate rates, differing fates: The rules of evolution changed from the Precambrian to the Phanerozoic. In: W. M. Fitch and F. J. Ayala (Eds.), Tempo and Mode in Evolution, Genetics and Paleontology 50 Years After Simpson (National Academy Press:, Washington, D.C.), 41-61.
32. SCHOPF, J. W. 1995. Human history and evolution: From Darwin to my students. In: B. F. Poglazov, B. I. Kurganov, M. S. Kritsky and K. L. Gladilin (Eds.) Evolutionary Biochemistry and Related Areas of Physiocochemical Biology (Bach Institute of Biochemistry and ANKO: Moscow), pp. 19-22.
33. SCHOPF, J. W. 1995. Metabolic memories of Earth's earliest biosphere. In: C. Marshall and J.W. Schopf (Eds), Evolution and the Molecular Revolution (Jones and Bartlett: Boston, MA), 73-107.
34. ALTERMANN, W. and SCHOPF, J. W. 1995. Microfossils from the Neoarchean Campbell Group, Griqualand West Sequence of the Transvaal Supergroup, and their paleoenvironmental and evolutionary implications. Precambrian Res. **75**: 65-90.
35. SCHOPF, J. W. 1995. Evolution, the GUT of biology. In: Mader, S.S., Biology , 5th edition (Wm. C. Brown: Dubuque, IA), p. 2.
36. SCHOPF, J. W. 1996. Cyanobacteria: Pioneers of the early Earth. - Desikachary Festschrift Volume, Nova Hedwigia **112**: 13-32

37. SCHOPF, J. W. 1996.. Are the oldest fossils cyanobacteria? In: Roberts, D. McL., Sharp, P., Alderson, G. and Collins, M. (Eds.), Evolution of Microbial Life, Society for General Microbiology Symposium 54 (Cambridge Univ. Press: Cambridge, UK), pp. 23 - 61.
38. FAIRCHILD, T. R., SCHOPF, J. W., SHEN-MILLER, J., GUIMARÃES, E. M., EDWARDS, M. D., LAGSTEIN, A., LI, X., PABST, M. and de MELO-FILO, L. S. 1996. Recent discoveries of Proterozoic microfossils in south-central Brazil. Precambrian Res. **80**: 125-152.
39. MILLER, S. L., SCHOPF, J. W. AND LAZCANO, A. 1997. Oparin's "Origin of Life:" Sixty years later. Journal of Molecular Evolution **44**: 353-353.

BOOK-RELATED ITEMS (Prefaces, Glossaries, Indices)

1. SCHOPF, J. W. 1992. Preface. In: J. W. Schopf (Ed.), Major Events in the History of Life (Jones and Bartlett: Boston, MA), pp. xii-xv.
2. SCHOPF, J. W. 1992. Glossary. In: J. W. Schopf (Ed.), Major Events in the History of Life (Jones and Bartlett: Boston, MA), pp. 177-184.
3. SCHOPF, J.W. 1992. Subject Index. In: J. W. Schopf (Ed.), Major Events in the History of Life (Jones and Bartlett: Boston, MA), pp. 85-190.
4. SCHOPF, J. W. & KLEIN, C. 1992. Preface. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), xxi-xxiv.
5. SCHOPF, J. W. & KLEIN, C. 1992. Glossary of technical terms. Chapter 27. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 1189-1203.
6. SCHOPF, J. W. & KLEIN, C. 1992. Subject index. In: J. W. Schopf and C. Klein (Eds.), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 1287-1295.
7. SCHOPF, J. W. 1992. Taxonomic index. In: J. W. Schopf and C. Klein (Eds), The Proterozoic Biosphere, A Multidisciplinary Study (Cambridge Univ. Press: New York, NY), pp. 1309-1348.
8. SCHOPF, J.W. 1994. Subject Index. In: J. H. Campbell & J. W. Schopf (Eds.), Creative Evolution?! (Jones and Bartlett: Boston, MA), pp. 109-112.
9. SCHOPF, J. W. 1994. Glossary. In: J. H. Campbell & J. W. Schopf (Eds.), Creative Evolution?! (Jones and Bartlett: Boston, MA), pp. 103-107.
10. MARSHALL, C. R. and SCHOPF, J. W. 1995. Preface. In: C. Marshall and J.W. Schopf (Eds), Evolution and the Molecular Revolution (Jones and Bartlett: Boston, MA), vii-x.
11. MARSHALL, C. R. and SCHOPF, J. W. 1995. Glossary. In: C. Marshall and J.W. Schopf (Eds), Evolution and the Molecular Revolution (Jones and Bartlett: Boston, MA), 149-160.
12. SCHOPF, J. W. 1995. Index. In: C. Marshall and J.W. Schopf (Eds), Evolution and the Molecular Revolution (Jones and Bartlett: Boston, MA), 161-166.
13. SCHOPF, J. W. 1997. Biographical sketches. In: A. B. Scheibel and J. W. Schopf (Eds), The Origin and Evolution of Intelligence (Jones and Bartlett: Boston, MA), xi-xiii.
14. SCHOPF, J. W. and SCHEIBEL, A. B. 1997. Glossary. In: A. B. Scheibel and J. W. Schopf (Eds), The Origin and Evolution of Intelligence (Jones and Bartlett: Boston, MA), 161-164.

15. SCHOPF, J. W. 1997. Index. In: A. B. Scheibel and J. W. Schopf (Eds), The Origin and Evolution of Intelligence (Jones and Bartlett: Boston, MA), 165-169.

MISCELLANEOUS PUBLICATIONS

1. SCHOPF, J. W. 1995. The oldest fossil evidence of life. Paleontological Society Brochures (The Paleontological Society), 7 pp.
2. SCHOPF, J. W. 1996. Confessions of a Mars skeptic. *Los Angeles Times,* August 18, 1996, p. M5.
3. SCHOPF, J. W. 1996. Scientist calls for rock-hard proof of Mars Life. *UCLA Today* **17**(2) [August 30, 1996), p. 4.

ABSTRACTS

1. SCHOPF, J. W. 1990. Paleo-environmental change: evolutionary responses. Abstracts and Program, Endangered Earth, an Evolutionary Perspective (Center for the Study of Evolution and the Origin of Life, UCLA), p. 6.
2. SCHOPF, J. W. 1990. What must be "true" for life to have originated on this planet? Program and Abstracts, 2nd Artificial Life Conference (Center for Nonlinear Studies, Santa Fe Institute, Santa Fe, New Mexico), p. 37.
3. SCHOPF, J. W. 1990. The 1990 William Smith Lecture: The earliest history of life -- solution to Darwin's dilemma. Geol. Soc. London Newsletter **19**(3): 13.
4. SCHOPF, J. W. 1990. Evolution of early life: microfossils and stromatolites. Abstracts, Fourth International Congress of Systematic and Evolutionary Biology (Univ. Maryland), p. 64.
5. SCHOPF, J. W. 1991. The oldest evidence of photosynthesis in the fossil record. Photochem. Photobiol. **53**(Suppl.): 5S-6S.
6. SCHOPF, J. W. 1991. Early Archean (~3.4 Ga) prokaryotic filaments from cherts of the Apex Basalt, Western Australia: the oldest cellularly preserved microfossils now known. In: R. A. Wharton, Jr., D. T. Anderson, S. E. Bzik, and J. D. Rummel (Eds.), Fourth Symposium on Chemical Evolution and the Origin and Evolution of Life (NASA Conference Publication 3129), p. 72.
7. SCHOPF, J. W. 1993. New evidence of the antiquity of life. Program and Abstracts, 7th ISSOL Meeting, 10th International Conference on the Origin of Life, Barcelona, Spain, p. 88.
8. BARTLEY, J. K. & SCHOPF, J. W. 1993. Carbon isotopic studies of microbial mats: Analogs for Precambrian ecosystems. Geol. Soc. Amer. Abstr. with Prog., **25**: A-356.
9. SCHOPF, J. W. 1994. The rules of evolution have changed. Program and Abstracts, Evolution and Extinction Seminar, Annual Meeting, AAAS, San Francisco:. p 5.
10. SCHOPF, J.W. 1994. As evidências mais antigas de vida na Terra: Implicações evolutivas e paleoambientais [The oldest evidence of life on Earth: Evolutionary and paleoenvironmental implications]. Roteiro de Excursão, Programma, Resumos Expandidos, IV Simpósio de Geologia do Centro-Oeste: Sociedade Brasileira de Geologia, Núcleos Brasília e Centro-Oeste [Excursion, Progam, and Extended Abstracts, 4th Symposium on West-Central Geology: Geological Society of Brazil, Brasilia and West-Central Section], p. 127.
11. SCHOPF, J. W. 1995. The oldest evidence of life on Earth. Program and Abstracts, Man and Universe -- A Sympoisum on the "Origins." Graduate University for Advanced Studies, Shonan Village Center (Hayama-machi, Kanagawa) and Pacifico Yokohama (Yokohama City, Kanagawa), Japan, pp. 17-18.

12. FAIRCHILD, T. R., SCHOPF, J. W., SHEN-MILLER, J., GUIMARÃES, E. M., SIMONETTI, C., EDWARDS, M. D., LAGSTEIN, A., LI, X., PABST, M. and de MELO-FILO, L. S. 1995. Microfósseis Proterozóicos da parte ocidental do Cráton do São Franciso, Brasil. V Simpósio de Geologia do Centro-Oeste, Goiânia, Sociedade Brasileira de Geologia, pp. 78-79.
13. SCHOPF, J. W. 1996. Modeling evolutionary tempo and mode: Are the right questions being asked? Fifth Annual Conference on Evolutionary Programming.
14. SCHOPF, J. W. 1996. Precambrian: The age of microscopic life. Sixth North American Paleontological Convention (NAC-96), Abstracts of Papers, (The Paleontological Society Special Publication No. 8), L. E. Babcock and W. I. Ausich, Editors, p. 345.
15. SCHOPF, J. W. 1997. The Oldest evidence of Life: Limitations of the rock record. Scientific Forum on The Origin of Life, Livets ursprung (Swedish Natural Science Research Council, Gothenburg, Sweden), p. 22.

IN PRESS

EDITED BOOK

1. SCHOPF, J. W. (Ed.). In Press.. Evolution! Facts and Fallacies (Academic Press: San Diego, CA), in press.

JOURNAL ARTICLES AND BOOK CHAPTERS

1. SCHOPF, J. W. In Press. Tracing the roots of the Universal Tree of Life. In: A. Brack (Ed.). The Molecular Origins of Life: Assembling Pieces of the Puzzle (Cambridge Univ. Press: New York).
2. SCHOPF, J. W. In Press. The Fossil Record: Tracing the roots of the Cyanobacterial Lineage. In: B. Whitton and M. Potts (Eds.), Ecology of Cyanobacteria: Their Diversity in Time and Space (Kluwer Academic: Dordrecht, The Netherlands).
3. SCHOPF, J. W. In Press. Breakthrough discoveries: Extraordinary claims! Extraordinary evidence? In: J.W. Schopf (Ed.), Evolution! Facts and Fallacies (Academic Press: San Diego, CA).

BOOK-RELATED ITEMS (Prefaces, Glossaries, Indices)

1. SCHOPF, J. W. In Press. Preface. In: J.W. Schopf (Ed.), Evolution! Facts and Fallacies (Academic Press: San Diego, CA).
2. SCHOPF, J. W. In Press. Glossary. In: J.W. Schopf (Ed.), Evolution! Facts and Fallacies (Academic Press: San Diego, CA).
3. SCHOPF, J. W. In Press. Index. In: J.W. Schopf (Ed.), Evolution! Facts and Fallacies (Academic Press: San Diego, CA).

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1/6/98	Final 1/1/90-9/30/97

4. TITLE AND SUBTITLE
Paleobiologic Studies of the Antiquity and Precambrian Evolution of Life

5. FUNDING NUMBERS
G
NAGW 2147

6. AUTHOR(S)
J. William Schopf

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Univ of California, Los Angeles
405 Hilgard Avenue
Los Angeles, CA ~~90024~~-1406
90095-

8. PERFORMING ORGANIZATION REPORT NUMBER
FINAL

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Dr. Michael Meyer/NASA Headquarters; Office of Space Sciences;Code SLC;Washington, DC 20546-0001
NASA Scientific & Tech. Inform. Facil.;P.O. Box 8757; Baltimore/Int. Airport,Maryland;Baltimore,Maryland 21240

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
See attached for FINAL report

14. SUBJECT TERMS	15. NUMBER OF PAGES 12
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102